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LONGEVITY AND MORTALITY IN DOGS OF FOUR BREEDS

A. COMFORT, Ph.D.

(From the Department of Zoology, University College, London)

The life span of dogs is known to vary from breed to breed, partly because some breeds are liable to specific, fatal diseases, and partly because of differences in general vigor. In the view of most breeders, there is not much difference in longevity between the common medium-sized breeds, but medium-sized and small dogs live longer than large (9), and outbred and mongrel dogs longer than inbred.

There are greater differences in size and physical proportion between the various types of pure bred dogs than in any other domestic mammal, and the breed characteristics are stable, if not genotypically uniform. Breed differences accordingly offer a possible source of information about the parts played by genetic and allometric characteristics, and factors such as inbreeding depression in determining the shape of the age/mortality function. Sacher (17) has recently revived the attempt to correlate life spans in mammalian species with body and brain proportion, notably the index of cephalization. A full set of dog life tables might be expected to show, among other things, how Sacher's correlation behaves with respect to artificially produced size variation within a species. At least so far as parenchymatous organs are concerned, size differences of this kind are predominantly differences in cell number (15). The same has been shown to apply to the relative numbers of posterior root fibers in great Danes and terriers (8) and may hold good for the number of neurones generally.

Nonquantitative impressions of the relative longevity of different breeds, attempts to derive formulae for equivalent ages in dog and man (2, 13), and records of known extreme ages are easily found, but actuarial data for dogs have proved extremely difficult to obtain, in spite of the vast numbers of dogs raised. A laboratory life table for beagles will eventually be available as a by-product of radiation research (1) but will take at least 15 years to complete. A previously published paper (3) gives some figures for Irish wolfhounds. The present paper gives additional curves, obtained from questionnaires sent to breeders, for small samples of pekinese, cocker spaniels, English mastiffs, and wolfhounds. Pending larger cross-sectional studies, these figures cover the size-range and suggest the possible character of the size-dependent differences which are likely to be encountered.

MATERIAL AND METHOD

The curves have been drawn from life histories of the following sample populations.

(a) 158 pekinese from 3 breeding kennels, D, K, and Y, of which 91 (39 males, 50 bitches, 2 unsexed) reached the age of 1 year.

(b) 45 cocker spaniels (7 males, 38 bitches) from kennel M.

(c) 23 English mastiffs (6 males, 17 bitches) bred between 1876 and 1893 and recorded in an older ledger in the library of the Kennel Club.

(d) 10 Irish wolfhounds (9 alive at one year) from kennel R, included for comparison with the 91 wolfhounds previously studied (3), which have been recomputed here with allowance for the losses excluded in the previous paper.

It is worth remarking that these series were the only satisfactory material for computation which was received in response to several hundred inquiries, supported by appeals in breeders' journals. The commonest defect in other records was the failure to keep full count of losses due to sale or accident, or to register all deaths. Several short series confined to adult

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TABLE 1. SURVIVAL OF 4 BREEDS OF DOGS FROM KENNEL RECORDS.

	Pekinese Kennels D, K, Y Pop. (a) ♂♀	Cocker Spaniels Kennel M Pop. (b) ♀	English Mastiffs Pop. (c) ♂♀	Irish Wolfhounds ‡C Pop. (d) ♂♀	Irish Wolfhounds Kennel R (Pop. (d) ♂♀
N*	91	38†	23	9	91
Age (Years)					
1	1.0000	1.0000	1.0000	1.0000	1.0000
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3	.9301	.9701	.8857	.....	.7019
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* N = number from total sample alive at 1 year.
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deaths without details of losses from the record were also received. These have not been included in the curves but give some confirmatory evidence of the distribution of natural death with age. Another complication was the possibility that there had been large changes in age/mortality distribution since breeders began to use effective vaccines against distemper and hardpad and against yellows; old series in which these diseases were heavily represented were excluded from the calculation.

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RESULTS AND DISCUSSION

It is evident from table 1 and figure 1, which give the short life tables of the 4 breeds and the derived survival curves, respectively, that the disadvantage in longevity attributed to large breeds is real. What is less clear, since the numbers are too small for reliable derivation of Gompertz' equations or for the estimation of the true shape of the details of the L_x distributions, is the nature of this disadvantage. The curve for spaniels has a long adult plateau and seems to approach the rectangular, optimal form found in man and hardy mammals generally, with a modal longevity of about 13 years; that for pekinese is similar, but with a higher early mortality. The curves for the large breeds might represent either the diagonal distribution seen in zoo animals (4) or a markedly higher rate of vigor loss with age. The difference between these two kinds of distribution has been

TABLE 2. DEATHS OF PUPPIES IN THE FIRST YEAR OF LIFE (CUMULATIVE MORTALITIES IN BRACKETS)*

	Kennel K			Kennel Y		
	♂	♀	Unsexed	♂	♀	Unsexed
N	49	50	7	13	20	6
Died:						
0-1 week	8 (.16)	9 (.18)	7 (1.0)	1 (.08)	5 (.25)	6 (1.0)
1 week-1 month	3 (.22)	7 (.32)	—	2 (.23)	— (.25)	—
1 month-1 year	7 (.37)	2 (.36)	—	— (.23)	— (.25)	

	D	K	Y
Total entries	13	107	38=158
Died under 1 year	—	43	15
Sold under 1 year	—	—	7
Alive at 1 year, no further record	—	2	—
	13	62	16=91

* Puppy mortality for kennel D not available.

TABLE 3. BRAIN WEIGHT, BODY WEIGHT, AND ASSUMED LIFE SPAN IN DOGS (SEE TEXT FOR EXPLANATION).

Breed	Body Wt. (Kg) y	Brain Wt. (Gm) z	log x_1	log x_2	log x^o	x^o (Years)
Pekinese	5.6	58.7	1.40	1.28	1.30	20
Dachshund	8.2	70.9	1.33	1.20	1.28	19
Fox terrier	7.8	67.9	1.31	1.18	1.20	(≤16)
Mastiff	42.2	116.5	1.30	1.17	1.15	14
Leonberger	47.6	113.0	1.29	1.28	1.15	14
St. Bernard	47.0	113.7	1.34	1.20	1.15	14

$\log x_1 = 0.636 \log z - 0.225 \log y + 1.035$ (Sacher's equation 17).
$\log x_2 = 0.6 \log z - 0.23 \log y + 0.99$.
x^o = observed or assumed life span.
Body and brain weights from Stephan (18).

discussed in another context (6); the distinction depends on the last decile. If the whole scale of mortality increase in large dogs is shortened compared with that in small, if in other words they age more rapidly, the difference between the last decile survival times of large and small dogs will be large. If they differ chiefly in the size of the standing mortality, as wild and zoo populations of sheep seem to differ (4), the maximum age records and the last decile values for large and small breeds should be closely similar.

The known distribution of maximum ages seems to support the first of these alternatives. I can find no record of a wolfhound or mastiff older than 14 years, but ages of 16 and 17 are reported in spaniels and of nearly 19 in pekinese. Hubbard's records (9) include fox terriers (age 20, 21, 21), Bedlington terrier (age 20), retriever (age 20), and Schipperke (age 24). He states that many toy breeds exceed the age of 12, some a few years longer, and a few exceed 20 years.

It seems likely that the last decile survival of all medium-sized breeds will prove to be much

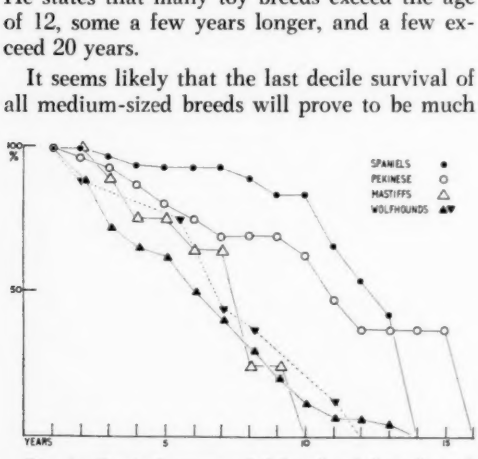

Fig. 1. Survival curves of 4 breeds of dogs from 1 year of age (see table 1).

the same, and that of the large group, including great Danes, St. Bernards, wolfhounds, mastiffs, and bull mastiffs, substantially less. Stockard (19) attributed many of the characters of these breeds to the inheritance of an abnormal level of pituitary activity. According to Klatt (10) the initial disturbance is probably an allometric increase in the growth rate of the whole front end of the animal, the pituitary being finally proportionate to the size of the head rather than of the dog; this is in accordance with the peculiar disproportion found in some of Stockard's crosses. Idiopathic diseases occur in several of the large breeds or in particular strains of them (bloat in bull mastiffs and osteogenic sarcoma in great Danes). According to Cotchin (7, 7a) the general liability of large dogs to bone tumors is greater than that of small, and, in a series of Cotchin's cases currently studied by Price (14), the age of onset in small, medium, and large breeds was found to be progressively earlier with increasing size. It would be of great interest to determine whether other diseases behave similarly and whether the order of their appearance is also size-dependent; as in radiation studies, analysis of the pattern of disease order and disease incidence is a possible means of discriminating between precocious aging, accelerated aging, and specific liability to single causes of death.

It is evident already from the available figures for brain and body weight in the various breeds (11, 12, 16, 18) that the differences in observed longevity follow the direction predicted by Sacher (17) from the distribution of life span with brain and body weight in different groups of mammalian species. Table 3 gives some of Stephan's data, together with the expected values of log x from Sacher's equation:

$$\log x = 0.636 \log z - 0.222 \log y + 1.035$$

where x = life span in years, y = body weight, and z = brain weight, both in grams. Comparing these with observed or assumed values of x (x^o), on the assumption that most of Sacher's figures for mammalian life spans are derived from maximum records and that the longevity of other big breeds which are known to be short-lived (such as the St. Bernard) resembles that of mastiffs, we find that most, although not all, of Stephan's data yield values for x which fit reasonably well to a similar equation with changed constants:

$$\log x = 0.6 \log z - 0.23 \log y + 0.99$$

The rest could no doubt be fitted by further manipulation, but more complex comparisons are pointless until the real life span of more breeds is known. The figures so far are at least consistent, however, with the idea that the rule regarding index of cephalization applies empirically to interbreed as well as interspecific differences.

SUMMARY

The survival curves of small series of pekinese, cocker spaniels, Irish wolfhounds, and great Danes were constructed from kennel records. The life span of the large breeds is considerably shorter than that of pekinese and spaniels. The relationship of these findings to the brain/body weight equation of Sacher is discussed.

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AGE DIFFERENCES IN THE SUCCINOXIDASE ACTIVITY OF HOMOGENATES AND MITOCHONDRIA FROM THE LIVERS AND KIDNEYS OF RATS

CHARLES H. BARROWS, JR., Sc.D., JOSEPH A. FALZONE, JR., M.D., Ph.D., AND NATHAN W. SHOCK, Ph.D.

(From the Gerontology Branch, National Heart Institute, National Institutes of Health, PHS, D.H.E.&W., Bethesda, and the Baltimore City Hospitals, Baltimore)

In a previous report from this laboratory (4), a decrement, associated with aging, in the concentration of succinoxidase in the kidney cortex of rats exceeded the decrement in the concentration of desoxyribosenucleic acid (DNA). No such changes were found in the liver. Similar decreases in the concentration of cytochrome c oxidase and succinic dehydrogenase were also reported in kidney homogenates. Since these enzymatic activities are believed to be associated with mitochondria (10), these results suggest that aging is accompanied by either: 1) a uniform reduction in the activities of these enzymes per mitochondrion or 2) a loss of mitochondria from kidney cells. The present study was an attempt to determine which of these alternatives is more likely. Thus the succinoxidase activities of whole homogenates as well as isolated mitochondria of liver and kidney cortex were measured in young (12-14 months) and old (24-27 months) rats of both sexes. In addition, another metabolic system associated with mitochondria, viz., succinate-stimulated oxidation phosphorylation, was measured in whole homogenates to determine whether an agewise decrement occurred in kidney cortex or in liver. The concentrations of DNA and protein nitrogen in the homogenates as well as the protein nitrogen contents of the mitochondrial preparations were determined.

MATERIALS AND METHODS

Animals.—All rats used in these studies were of the McCollum strain and were bred and maintained in our animal quarters. They were housed, 5 in a cage, on wood shavings in a room maintained at 75±2 F. A standard stock diet (3) was fed *ad libitum*. All animals were unmated. The various determinations were carried out on the tissues of young (12-14 months) and old (24-27 months) rats of both sexes.

Preparation of tissue samples.—Following decapitation of the animals, the organs were removed and placed in a moist Petri dish which was surrounded by cracked ice. Both isotonic sucrose and distilled water homogenates were prepared in a teflon tissue grinder immersed in an ice bath. Mitochondria were isolated by the method of Schneider (11). The turbidities of diluted aliquots of the mitochondrial suspensions were measured at 320 mμ on a Beckman DU spectrophotometer and the suspension adjusted to a standard turbidity before use in the metabolic studies.

Succinoxidase.—The succinoxidase activities of the isotonic sucrose homogenates and the mitochondrial suspensions of liver and kidney cortex were determined by the method of Schneider and Potter (12).

Oxidative phosphorylation.—Each Warburg flask contained in a final volume of 3.4 ml. orthophosphate, 54 μmoles; magnesium chloride, 20 μmoles; cytochrome c, 3.75 x 10^{-3} μmoles; glucose 60 μmoles; hexokinase, 0.5 mg. Sigma Type IV (145,000 K.M. units/Gm. [25 C.]) adenosine triphosphate, 5 μmoles; sodium fluoride, 30 μmoles; sodium succinate (sidearm), 7.5 μmoles; whole homogenate, 150 mg. wet weight. The center well contained 0.2 ml. of 10% potassium hydroxide. The reaction was carried out at 37 C. The flasks were flushed with oxygen for 3 minutes and equilibrated for an additional 5 minutes. The substrate was then tipped in and the reaction was followed for 20 minutes. At the end of the incubation period, the flasks were quickly removed and placed in an ice bath. An aliquot was immediately removed and added to a centrifuge tube containing trichloroacetic acid (final concentration 7%). Following precipitation of the protein, an aliquot of the supernatant was removed and analyzed for inorganic phosphate by the method of Lowry and Lopez (6). Control flasks contained no succinate.

Desoxyribose nucleic acid.—Samples for the measurement of DNA were prepared by the

TABLE 1. THE EFFECT OF AGE ON SUCCINATE STIMULATED METABOLISM OF WHOLE HOMOGENATES AND MITOCHONDRIA FROM KIDNEYS OF THE RAT.

	Females				Males			
	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$
Whole Homogenates								
N	13	11			10	13		
Succinoxidase ($mm.^3$ O_2/100 mg. wet wt./hr.)	3472±56	3096±112	.01	11	3292±116	2932±88	.01	11
Oxidative Phosphorylation								
O/μatoms/150 mg. wet wt./20 min.)	11.4±0.25	10.3±0.26	.01	11	11.9±0.20	10.06±0.36	.01	11
P(μmoles/150 mg. wet wt./20 min.)	19.1±0.31	17.0±0.94	.05	10	22.0±0.92	18.7±0.68	.01	15
P/O	1.7±0.04	1.7±0.08	NS	0	1.8±0.06	1.9±0.04	NS	−1
Deoxyribose Nucleic Acid (μg./100 mg. wet wt.)	366±6.0	356±7.5	NS	3	355±8.4	359±6.0	NS	−2
Protein Nitrogen (mg./100 mg. wet wt.)	2.52±0.024	2.44±0.045	NS	5	2.57±0.037	2.47±0.036	NS	4
Mitochondria								
Succinoxidase ($mm.^3$ O_2/mg. PN/hr.)	4014±106.8	4077±93.5	NS	−2	3902±68.0	3726±90.0	NS	4
Protein Nitrogen (μg./cc.[OD 320 mμ = 0.100])	47.2±1.40	47.6±1.44	NS	−1	51.6±0.84	49.2±10.6	NS	4

method of Schneider (9), and the DNA determined by the method of Stumpf (14).

Protein nitrogen.—The nitrogen content of the 7% cold trichloroacetic acid insoluble material of the various homogenates and mitochondrial suspensions was determined by the micro-Kjeldahl procedure of Hiller, Plazin, and Van Slyke (5).

RESULTS

Kidney.—A significant agewise decrease (11%) in the activities of succinoxidase of homogenates prepared from kidney cortical tissue of both male and female rats was observed (table 1). Similar age-dependent decreases in the rates of succinate-stimulated oxidation and phosphorylation of these homogenates were also found. In contrast, the concentration of DNA and protein nitrogen per unit wet weight were not decreased in the kidney tissue of the old rats. No age-dependent decrements in the succinoxidase activity based on the protein nitrogen content of mitochondria isolated from kidney cortical tissue were established. A comparison of the protein nitrogen content of mitochondria based on the turbidimetric estimation of the number of particles within the suspension also failed to demonstrate any agewise differences.

Liver. — No statistically significant age changes were found in liver tissue (table 2).

DISCUSSION

The data of this experiment agree with our previous report that a greater decrement in the concentration of succinoxidase as compared to that of DNA per unit wet weight is found in the kidney but not the liver of senescent rats. The magnitude of this decrement, viz., 11%, is approximately equal to that previously observed. In this experiment, the rates of oxidative phosphorylation were decreased in kidney homogenates approximately the same per cent as the concentration of succinoxidase. The evidence that these changes represent a loss of mitochondria rather than changes in the enzyme concentrations per mitochondrion is found in the lack of an age difference in the concentration of succinoxidase per unit of mitochondrial protein nitrogen.

In the interpretation of these observations, it was assumed that 1) the protein nitrogen content of mitochondria was constant with age and 2) no selection of mitochondria occurred during the isolation procedure. A comparison of the protein nitrogen content of mitochondria based on the turbidimetric estimation of the number of particles within the suspension failed

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Survival curves were drawn after computing life tables by yearly intervals, starting at 1 year of age, with allowance for losses, as described in the case of racehorse records (5). Deaths due to disease, whelping, or destruction by reason of incurable disease were scored as natural, all others as losses (table 1). Puppy mortality was not available for kennel D of sample (a), or for samples (b), (c), or (d). Losses from birth to 1 year at kennels K and Y are shown separately (table 2) to complete the distribution. The curves for (a), (c), and (d) are plotted for the combined sexes, that for (b) for bitches only, as there was reason to suspect selection of the 7 males in this series.

RESULTS AND DISCUSSION

It is evident from table 1 and figure 1, which give the short life tables of the 4 breeds and the derived survival curves, respectively, that the disadvantage in longevity attributed to large breeds is real. What is less clear, since the numbers are too small for reliable derivation of Gompertz' equations or for the estimation of the true shape of the details of the L_x distributions, is the nature of this disadvantage. The curve for spaniels has a long adult plateau and seems to approach the rectangular, optimal form found in man and hardy mammals generally, with a modal longevity of about 13 years; that for pekinese is similar, but with a higher early mortality. The curves for the large breeds might represent either the diagonal distribution seen in zoo animals (4) or a markedly higher rate of vigor loss with age. The difference between these two kinds of distribution has been

TABLE 2. DEATHS OF PUPPIES IN THE FIRST YEAR OF LIFE (CUMULATIVE MORTALITIES IN BRACKETS)*

	Kennel K			Kennel Y		
	♂	♀	Unsexed	♂	♀	Unsexed
N	49	50	7	13	20	6
Died:						
0-1 week	8 (.16)	9 (.18)	7 (1.0)	1 (.08)	5 (.25)	6 (1.0)
1 week-1 month	3 (.22)	7 (.32)	—	2 (.23)	— (.25)	—
1 month-1 year	7 (.37)	2 (.36)	—	— (.23)	— (.25)	

	D	K	Y
Total entries	13	107	38=158
Died under 1 year	—	43	15
Sold under 1 year	—	—	7
Alive at 1 year, no further record	—	2	—
	13	62	16=91

* Puppy mortality for kennel D not available.

TABLE 3. BRAIN WEIGHT, BODY WEIGHT, AND ASSUMED LIFE SPAN IN DOGS (SEE TEXT FOR EXPLANATION).

Breed	Body Wt. (Kg) y	Brain Wt. (Gm) z	log x_1	log x_2	log x°	x° (Years)
Pekinese	5.6	58.7	1.40	1.28	1.30	20
Dachshund	8.2	70.9	1.33	1.20	1.28	19
Fox terrier	7.8	67.9	1.31	1.18	1.20	(≤16)
Mastiff	42.2	116.5	1.30	1.17	1.15	14
Leonberger	47.6	113.0	1.29	1.28	1.15	14
St. Bernard	47.0	113.7	1.34	1.20	1.15	14

$\log x_1 = 0.636 \log z - 0.225 \log y + 1.035$ (Sacher's equation 17).
$\log x_2 = 0.6 \log z - 0.23 \log y + 0.99$.
x° = observed or assumed life span.
Body and brain weights from Stephan (18).

discussed in another context (6); the distinction depends on the last decile. If the whole scale of mortality increase in large dogs is shortened compared with that in small, if in other words they age more rapidly, the difference between the last decile survival times of large and small dogs will be large. If they differ chiefly in the size of the standing mortality, as wild and zoo populations of sheep seem to differ (4), the maximum age records and the last decile values for large and small breeds should be closely similar.

The known distribution of maximum ages seems to support the first of these alternatives. I can find no record of a wolfhound or mastiff older than 14 years, but ages of 16 and 17 are reported in spaniels and of nearly 19 in pekinese. Hubbard's records (9) include fox terriers (age 20, 21, 21), Bedlington terrier (age 20), retriever (age 20), and Schipperke (age 24). He states that many toy breeds exceed the age of 12, some a few years longer, and a few exceed 20 years.

It seems likely that the last decile survival of all medium-sized breeds will prove to be much

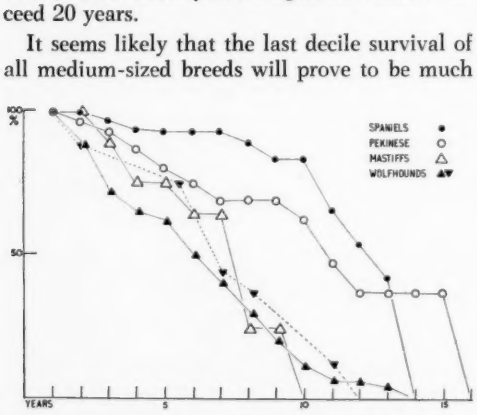

Fig. 1. Survival curves of 4 breeds of dogs from 1 year of age (see table 1).

the same, and that of the large group, including great Danes, St. Bernards, wolfhounds, mastiffs, and bull mastiffs, substantially less. Stockard (19) attributed many of the characters of these breeds to the inheritance of an abnormal level of pituitary activity. According to Klatt (10) the initial disturbance is probably an allometric increase in the growth rate of the whole front end of the animal, the pituitary being finally proportionate to the size of the head rather than of the dog; this is in accordance with the peculiar disproportion found in some of Stockard's crosses. Idiopathic diseases occur in several of the large breeds or in particular strains of them (bloat in bull mastiffs and osteogenic sarcoma in great Danes). According to Cotchin (7, 7a) the general liability of large dogs to bone tumors is greater than that of small, and, in a series of Cotchin's cases currently studied by Price (14), the age of onset in small, medium, and large breeds was found to be progressively earlier with increasing size. It would be of great interest to determine whether other diseases behave similarly and whether the order of their appearance is also size-dependent; as in radiation studies, analysis of the pattern of disease order and disease incidence is a possible means of discriminating between precocious aging, accelerated aging, and specific liability to single causes of death.

It is evident already from the available figures for brain and body weight in the various breeds (11, 12, 16, 18) that the differences in observed longevity follow the direction predicted by Sacher (17) from the distribution of life span with brain and body weight in different groups of mammalian species. Table 3 gives some of Stephan's data, together with the expected values of log x from Sacher's equation:

$$\log x = 0.636 \log z - 0.222 \log y + 1.035$$

where x = life span in years, y = body weight, and z = brain weight, both in grams. Comparing these with observed or assumed values of x (x^o), on the assumption that most of Sacher's figures for mammalian life spans are derived from maximum records and that the longevity of other big breeds which are known to be short-lived (such as the St. Bernard) resembles that of mastiffs, we find that most, although not all, of Stephan's data yield values for x which fit reasonably well to a similar equation with changed constants:

$$\log x = 0.6 \log z - 0.23 \log y + 0.99$$

The rest could no doubt be fitted by further manipulation, but more complex comparisons are pointless until the real life span of more breeds is known. The figures so far are at least consistent, however, with the idea that the rule regarding index of cephalization applies empirically to interbreed as well as interspecific differences.

SUMMARY

The survival curves of small series of pekinese, cocker spaniels, Irish wolfhounds, and great Danes were constructed from kennel records. The life span of the large breeds is considerably shorter than that of pekinese and spaniels. The relationship of these findings to the brain/body weight equation of Sacher is discussed.

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AGE DIFFERENCES IN THE SUCCINOXIDASE ACTIVITY OF HOMOGENATES AND MITOCHONDRIA FROM THE LIVERS AND KIDNEYS OF RATS

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In a previous report from this laboratory (4), a decrement, associated with aging, in the concentration of succinoxidase in the kidney cortex of rats exceeded the decrement in the concentration of desoxyribosenucleic acid (DNA). No such changes were found in the liver. Similar decreases in the concentration of cytochrome c oxidase and succinic dehydrogenase were also reported in kidney homogenates. Since these enzymatic activities are believed to be associated with mitochondria (10), these results suggest that aging is accompanied by either: 1) a uniform reduction in the activities of these enzymes per mitochondrion or 2) a loss of mitochondria from kidney cells. The present study was an attempt to determine which of these alternatives is more likely. Thus the succinoxidase activities of whole homogenates as well as isolated mitochondria of liver and kidney cortex were measured in young (12-14 months) and old (24-27 months) rats of both sexes. In addition, another metabolic system associated with mitochondria, viz., succinate-stimulated oxidation phosphorylation, was measured in whole homogenates to determine whether an agewise decrement occurred in kidney cortex or in liver. The concentrations of DNA and protein nitrogen in the homogenates as well as the protein nitrogen contents of the mitochondrial preparations were determined.

MATERIALS AND METHODS

Animals.—All rats used in these studies were of the McCollum strain and were bred and maintained in our animal quarters. They were housed, 5 in a cage, on wood shavings in a room maintained at 75±2 F. A standard stock diet (3) was fed *ad libitum*. All animals were unmated. The various determinations were carried out on the tissues of young (12-14 months) and old (24-27 months) rats of both sexes.

Preparation of tissue samples.—Following decapitation of the animals, the organs were removed and placed in a moist Petri dish which was surrounded by cracked ice. Both isotonic sucrose and distilled water homogenates were prepared in a teflon tissue grinder immersed in an ice bath. Mitochondria were isolated by the method of Schneider (11). The turbidities of diluted aliquots of the mitochondrial suspensions were measured at 320 mμ on a Beckman DU spectrophotometer and the suspension adjusted to a standard turbidity before use in the metabolic studies.

Succinoxidase.—The succinoxidase activities of the isotonic sucrose homogenates and the mitochondrial suspensions of liver and kidney cortex were determined by the method of Schneider and Potter (12).

Oxidative phosphorylation.—Each Warburg flask contained in a final volume of 3.4 ml. orthophosphate, 54 μmoles; magnesium chloride, 20 μmoles; cytochrome c, 3.75 x 10^{-1} μmoles; glucose 60 μmoles; hexokinase, 0.5 mg. Sigma Type IV (145,000 K.M. units/Gm. [25 C.]) adenosine triphosphate, 5 μmoles; sodium fluoride, 30 μmoles; sodium succinate (sidearm), 7.5 μmoles; whole homogenate 150 mg. wet weight. The center well contained 0.2 ml. of 10% potassium hydroxide. The reaction was carried out at 37 C. The flasks were flushed with oxygen for 3 minutes and equilibrated for an additional 5 minutes. The substrate was then tipped in and the reaction was followed for 20 minutes. At the end of the incubation period, the flasks were quickly removed and placed in an ice bath. An aliquot was immediately removed and added to a centrifuge tube containing trichloroacetic acid (final concentration 7%). Following precipitation of the protein, an aliquot of the supernatant was removed and analyzed for inorganic phosphate by the method of Lowry and Lopez (6). Control flasks contained no succinate.

Desoxyribose nucleic acid.—Samples for the measurement of DNA were prepared by the

TABLE 1. THE EFFECT OF AGE ON SUCCINATE STIMULATED METABOLISM OF WHOLE HOMOGENATES AND MITOCHONDRIA FROM KIDNEYS OF THE RAT.

	Females				Males			
	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$
Whole Homogenates								
N	13	11			10	13		
Succinoxidase ($mm.^3$ O_2/100 mg. wet wt./hr.)	3472±56	3096±112	.01	11	3292±116	2932±88	.01	11
Oxidative Phosphorylation								
O/μatoms/150 mg. wet wt./20 min.)	11.4±0.25	10.3±0.26	.01	11	11.9±0.20	10.06±0.36	.01	11
P/μmoles/150 mg. wet wt./20 min.)	19.1±0.31	17.0±0.94	.05	10	22.0±0.92	18.7±0.68	.01	15
P/O	1.7±0.04	1.7±0.08	NS	0	1.8±0.06	1.9±0.04	NS	−1
Desoxyribose Nucleic Acid (μg./100 mg. wet wt.)	366±6.0	356±7.5	NS	3	355±8.4	359±6.0	NS	−2
Protein Nitrogen (mg./100 mg. wet wt.)	2.52±0.024	2.44±0.045	NS	5	2.57±0.037	2.47±0.036	NS	4
Mitochondria								
Succinoxidase ($mm.^3$ O_2/mg. PN/hr.)	4014±106.8	4077±93.5	NS	−2	3902±68.0	3726±90.0	NS	4
Protein Nitrogen (μg./cc.[OD 320 mμ = 0.100])	47.2±1.40	47.6±1.44	NS	−1	51.6±0.84	49.2±10.6	NS	4

method of Schneider (9), and the DNA determined by the method of Stumpf (14).

Protein nitrogen.—The nitrogen content of the 7% cold trichloroacetic acid insoluble material of the various homogenates and mitochondrial suspensions was determined by the micro-Kjeldahl procedure of Hiller, Plazin, and Van Slyke (5).

RESULTS

Kidney.—A significant agewise decrease (11%) in the activities of succinoxidase of homogenates prepared from kidney cortical tissue of both male and female rats was observed (table 1). Similar age-dependent decreases in the rates of succinate-stimulated oxidation and phosphorylation of these homogenates were also found. In contrast, the concentration of DNA and protein nitrogen per unit wet weight were not decreased in the kidney tissue of the old rats. No age-dependent decrements in the succinoxidase activity based on the protein nitrogen content of mitochondria isolated from kidney cortical tissue were established. A comparison of the protein nitrogen content of mitochondria based on the turbidimetric estimation of the number of particles within the suspension also failed to demonstrate any agewise differences.

Liver. — No statistically significant age changes were found in liver tissue (table 2).

DISCUSSION

The data of this experiment agree with our previous report that a greater decrement in the concentration of succinoxidase as compared to that of DNA per unit wet weight is found in the kidney but not the liver of senescent rats. The magnitude of this decrement, viz., 11%, is approximately equal to that previously observed. In this experiment, the rates of oxidative phosphorylation were decreased in kidney homogenates approximately the same per cent as the concentration of succinoxidase. The evidence that these changes represent a loss of mitochondria rather than changes in the enzyme concentrations per mitochondrion is found in the lack of an age difference in the concentration of succinoxidase per unit of mitochondrial protein nitrogen.

In the interpretation of these observations, it was assumed that 1) the protein nitrogen content of mitochondria was constant with age and 2) no selection of mitochondria occurred during the isolation procedure. A comparison of the protein nitrogen content of mitochondria based on the turbidimetric estimation of the number of particles within the suspension failed

TABLE 2. THE EFFECT OF AGE ON SUCCINATE STIMULATED METABOLISM OF WHOLE HOMOGENATES AND MITOCHONDRIA FROM LIVERS OF THE RAT.

	Females				Males			
	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$	Young	Old	$P_{diff.}$	$\frac{\text{Young-Old}}{\text{Young}} \times 100$
Whole Homogenates								
N	13	11			10	13		
Succinoxidase ($mm.^3$ O_2/100 mg. wet wt./hr.)	2472±88	2416±48	NS	2	2268±72	2296±80	NS	1
Oxidative Phosphorylation								
O(μatoms/150 mg. wet wt./20 min.)	7.4±0.28	7.3±0.26	NS	1	8.1±0.25	7.9±0.19	NS	0
P(μmoles/150 mg. wet wt./20 min.)	14.0±0.69	12.7±0.81	NS	9	15.6±0.72	15.0±0.63	NS	2
P/O	1.9±0.09	1.7±0.09	NS	10	1.9±0.10	1.9±0.08	NS	0
Desoxyribose Nucleic Acid (μg./100mg. wet wt.)	342±7.6	347±5.3	NS	−1	292 ±12.0	311±12.5	NS	−7
Protein Nitrogen (mg./100 mg. wet wt.)	2.83±0.045	2.82±0.018	NS	0	2.77±0.048	2.86±0.049	NS	−3
Mitochondria								
Succinoxidase ($mm.^3$ O_2/mg. PN/hr.)	2639±117.5	2671±104.5	NS	−1	2211±111.7	2271±61.9	NS	−3
Protein Nitrogen (μg./cc.[OD 320mμ=0.100])	26.4±0.72	28.0±0.68	NS	−5	28.4±0.52	28.4±1.08	NS	0

to demonstrate any agewise difference. It is obvious that any age-dependent change in size or shape of the mitochondria may influence this finding. Therefore, actual mitochondrial counts are needed for final proof. However, the reliability of the method of counting mitochondria is inadequate to demonstrate the small loss of mitochondria (10%) suggested by the biochemical studies. Nevertheless, these data may be used to support the second assumption. Estimates of the number of mitochondria per gram of tissue may be obtained by dividing the succinoxidase activity per unit wet weight of tissues by the succinoxidase activity per mitochondrion. If only those mitochondria containing high concentrations of succinoxidase were obtained and the others lost during the isolation procedure, the value for the succinoxidase per mitochondrion would be higher than the true average. This would result in unusually low estimates of the number of mitochondria per gram of tissue. However, when counts were made on suspensions of mitochondria isolated from the livers and kidneys of 23 of the animals in this study, the calculated number of mitochondria per gram was 407 x 10^9 for liver and 378 x 10^9 for kidney cortex. These values are as high or higher than those reported in other studies (1,2,7,8,13).

The data of this experiment offer no evidence for an agewise change in the metabolic activity of mitochondria isolated from kidney cortex or liver when succinate is used as the substrate. Similar results were obtained by Weinbach and Garbus (16) who could find no age differences in the rates of oxidative phosphorylation stimulated by a variety of Krebs citric acid cycle intermediates in mitochondria isolated from rat liver or brain. Tonna (15), using histological techniques, observed that the activities of respiratory enzymes in the periosteum of rats of different ages paralleled the numbers of mitochondria in the test preparations. Therefore, taken as a whole, these data suggest that the agewise decrement in the metabolic activity stimulated by succinate in whole homogenates of kidney cortex results from a loss of mitochondria from the tissue, rather than from a change in the concentration of the enzymes per mitochondrion.

SUMMARY

Measurement of the rates of oxidative phosphorylation stimulated by succinate and the concentration of succinoxidase and DNA of homogenates prepared from livers of 12-14-month-old and 24-27-month-old rats failed to indicate any agewise differences. Similarly, no

age-dependent differences in the succinoxidase activities of mitochondria isolated from this organ were observed. However, although no decrement associated with aging in the concentration of DNA occurred, the rates of oxidative phosphorylation and the concentration of succinoxidase were significantly decreased in homogenates prepared from kidney cortex of the older animals. Since the succinoxidase activity of mitochondria isolated from this tissue was not different in the animals of the two age groups, these data seem to indicate that the agewise decrement in the metabolic activity stimulated by succinate of whole homogenates of kidney cortex results from a loss of mitochondria from the tissue rather than changes in the concentration of the enzymes per mitochondrion.

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STRAIN DIFFERENCES AND THE DEVELOPMENT OF FATTY LIVER IN THE AGED RAT*

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In a previous study (1) it was found that 20 of 21 aged male rats of a locally inbred Osborne-Mendel strain had grossly fatty enlarged livers while 24 neonatally castrated litter mates did not. The animals of this inbred strain, and all other Duke University Osborne-Mendel rats, are derived from animals brought from Vanderbilt University to Duke approximately 20 years ago. The inbred strain is the result of brother-sister matings during the past 18 years. The remaining Osborne-Mendel animals have been randomly mated, with no outside strain being introduced and no attempt at selective inbreeding. These animals are here called colony-bred and were used to determine whether or not aged males and/or females, treated as were the males of the inbred strain, would also develop excessive hepatic fat.

MATERIALS AND METHODS

Eighteen aged male rats (554-696 days) and 21 aged females (350-722 days) of a locally colony-bred Osborne-Mendel strain were divided into 7 groups as indicated in table 1. The data in Group VIII from 7 of the aged male rats of a locally inbred strain (1) are repeated from the previous study for the purpose of comparison. In the previous study all the animals were injected with 0.5 cc. sesame oil every day for the week prior to being killed; therefore, in the present study 5 males (Group III) and 4 females (Group VII) were similarly injected. All animals were anesthetized with a subcutaneous injection of 55 μg Nembutal®/kg. body weight. A midline laparotomy was performed and *in vivo* observations of the liver were made using the quartz rod method of Knisely (2). Following the *in vivo* studies a small sample of liver (approximately 50 mg.) was taken from the living animal to prepare H and E and fat stained sections. The remainder of the liver was removed, weighed, dried for 3 days at 120 C., and fat was extracted with petroleum benzin. All animals were similarly caged and fed Purina Fox Chow and water *ad libitum* as were those in the previous report (1). The data were analyzed by the paired group method using Student's "t," and the significance determined with the aid of tables of probability (4).

RESULTS

Neither males nor females of the colony-bred strain showed gross evidence of an increase in hepatic fat (table 1). Microscopic observations of the living livers demonstrated no abnormalities, and males and females in all groups had normal parenchymal and vascular patterns. There was no *in vivo* evidence of excess hepatic fat.

The histological structure of the liver was essentially normal with only a slight degree of nuclear pyknosis and cytoplasmic vacuolization in both the males and females beyond 560 days of age. The data on extracted fat were similar to the gross and microscopic observations (table 1). Although the 350-day-old females had more hepatic fat than did those 560 days of age, there was a tendency for increased age to be accompanied by increased liver fat in both males and females. Those animals approximately 550 days of age had less than 12.5 mg. fat/gm. liver, while all animals which were approximately 700 days of age had more than 17 mg. fat/gm. liver, and this was statistically significant for both sexes ($P < .005$).

DISCUSSION

While there was a statistically significant increase in liver fat with increased age in both males and females in the colony-bred animals, the increment of fat was much less than in the inbred animals (1). Thus, while the present study reinforces the significance of increased age as a factor in the development of fatty liver in the rat, it also suggests the importance of

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TABLE 1. EXTRACTED HEPATIC FAT FROM AGED COLONY-BRED AND INBRED OSBORNE-MENDEL RATS.

Group	Animals	Strain	No. of Animals	No. with Fatty Liver	Age in Days*	Wt. Gm.	Liver Wt. Gm.	Mg. Fat/Gm. Liver
I	Untreated Male	C.B.	8	0	554	415 (365–460)	12.23 (10.45–19.07)	6.2±0.4† (1.3–12.7)
II	Untreated Male	C.B.	5	0	696	486 (440–516)	14.64 (12.84–17.47)	27.1±0.7 (18.9–27.4)
III	Male+S.O.	C.B.	5	0	696	492 (460–516)	13.25 (10.57–15.57)	23.6±1.3 (17.4–29.1)
IV	Untreated Female	C.B.	8	0	350	264 (220–320)	8.76 (6.76–10.10)	20.9±1.5 (10.9–49.2)
V	Untreated Female	C.B.	6	0	560	305 (260–340)	9.09 (8.02–11.21)	10.0±0.4 (7.5–12.1)
VI	Untreated Female	C.B.	3	0	722	330 (315–342)	10.61 (9.25–11.83)	24.3±2.3 (17.5–31.4)
VII	Female + S.O.	C.B.	4	0	722	320 (307–334)	9.50 (8.35–11.69)	25.6±1.1 (21.8–31.0)
VIII	Male + S.O.	I.B.	7	7	665 (571–821)	354 (320–410)	14.11 (12.46–15.40)	166.1±8.5‡ (140.8–191.8)

S.O. = Sesame oil (0.5 cc. q.d.× 7 prior to death)
C.B. = Colony-bred strain
I.B. = Inbred strain from previous report (1)
* Animals in each of Groups I-VII are all the same age.
† = Standard error of the mean.
‡ = Only 3 livers analyzed for fat.

genetic factors in this regard. Despite the fact that both strains were derived from a common source there was a marked difference in response between the two groups in regard to the production of fatty liver. Mickelsen, Takahashi, and Craig (3) presented data which may suggest that Osborne-Mendel rats handle ingested fat differently than do either NIH Black rats or Sprague-Dawley rats. These data may suggest that the inbred animals handle ingested fat differently than do the colony-bred rats.

A previous study (1) suggested the requirements of both testes and old age for the development of fatty liver in the inbred Osborne-Mendel strain. The present data suggest the possibility that genetic factors are also of importance in this regard.

Although the hepatic fat was not excessive in any of the colony-bred animals, there was a significant increase in older animals of both sexes. The only group not fitting this trend was the 350-day-old colony-bred females which had more hepatic fat than did those 560 days of age. There is no explanation of this fact which can be given at present. However, experiments now being carried out may shed some light on this.

SUMMARY

Hepatic fat in a colony-bred strain of aged Osborne-Mendel rats has been compared with previously reported results on males from an inbred Osborne-Mendel strain. None of the 18 males or 21 females of the colony-bred strain had a grossly fatty liver, which contrasts with a massive accumulation of hepatic fat in the 7 inbred animals taken for comparison. While the data confirm the previous observation that old animals have more hepatic fat than do young ones, the 350-day-old females did have more fat than did 560-day-old females. This is the only contradiction of the trend of increasing fat with increasing age.

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THE LEUCINE AMINOPEPTIDASE ACTIVITY OF ARTERIAL TISSUE IN INDIVIDUALS OF VARIOUS AGES*

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The presence in human arterial tissue of leucine aminopeptidase activity was reported in 1955 by Green and associates (1), but only 3 aortic samples were included in the study. The present investigation was undertaken with the purpose of determining the activity of this enzyme in a large number of arterial samples obtained fresh at autopsy from individuals of various ages; a further aim of the study was to compare the enzyme activities of normal and arteriosclerotic tissue portions.

MATERIALS AND METHODS

Seventy-eight samples of the thoracic descending aorta, 74 samples of the pulmonary artery, and 51 samples of the coronary artery were included in the study. The enzyme activity determinations were performed on aqueous homogenates of intima-media layers of the arteries; in the case of the aortic and coronary artery samples the measurements were made separately on normal and arteriosclerotic tissue portions of the same blood vessels. The procedure of Green and associates (1) was employed for the leucine aminopeptidase determinations; in this method L-leucyl-beta-naphthylamide hydrochloride is used as substrate for the enzyme, and the hydrolysis product of the reaction, beta-naphthylamine, is determined colorimetrically.

The final millimolar concentrations used (total volume, 8.0 ml.) were: L-leucyl-beta-naphthylamide hydrochloride (Dajac Laboratories, Borden Chemical Company), 0.65; veronal, 50.0; the pH of the buffer-substrate mixture was 8.2. An amount of homogenate corresponding to 40 mg. of fresh tissue was employed in each test. A reagent blank was run with each set of analyses.

The samples were incubated for 1 hour at 38 C. in a water bath provided with a shaking mechanism, and 3.0 ml. aliquots of the incubation mixture were removed at 0 and 60 minutes. Each aliquot was added to 3.0 ml. of 10% trichloroacetic acid contained in a test tube. After centrifugation, 3.0 ml. of the supernatant were used for determination of the quantity of beta-naphthylamine present in the sample. The colorimetric determination was performed by the modification of the Bratton-Marshall procedure described by Green and associates (1). The readings were made at 570 mμ in a Beckman DU spectrophotometer; for greater accuracy a set of cuvettes with a light path of 100 mm. (Beckman No. 40747) was used for the colorimetric measurements.

The K_m observed for L-leucyl-beta-naphthylamide hydrochloride was 3.8×10^{-5} M. A high degree of proportionality was found between time of incubation and recorded enzyme activities over a 150-minute period for a 20-80 mg. tissue range.

RESULTS

The mean leucine aminopeptidase activities of aortic, pulmonary artery, and coronary artery samples observed for various age groups have been listed in table 1.

Aortic samples.—The average leucine aminopeptidase value observed for normal aortic samples was 1.34 mg. beta-naphthylamine liberated/Gm. wet tissue/hour. A moderate tendency was noted for the enzyme activity to decrease with age when the values were expressed on the basis of wet tissue weight, whereas no significant correlation between age and enzyme values was observed when the activities were calculated on the basis of the tissue nitrogen content (table 2).

A comparison of the mean leucine aminopeptidase activities of arteriosclerotic and normal tissue portion of the same blood vessels showed no significant difference between the values (table 3).

Pulmonary artery samples.—The leucine aminopeptidase activities observed for the pulmonary artery samples (table 1) were of the same magnitude as those found for the aortic tissue, the average value being 1.32 mg. beta-naphthylamine liberated/Gm. wet tissue/hour. In accordance with the findings for the aortic samples, the enzyme activity showed a slight tendency to decrease with age when calculated on the basis of the wet tissue weight (table 2).

Coronary artery samples.—As seen from table 1, the mean leucine aminopeptidase activity recorded for the normal coronary artery samples (1.57 mg. beta-naphthylamine liberated/Gm. wet tissue/hour) was somewhat higher than the average values found for the aortic and

* Studies on Arterial Metabolism XXIX. The investigation was supported by a grant from the National Institutes of Health, Public Health Service (PHS-891).

TABLE 1. MEAN LEUCINE AMINOPEPTIDASE ACTIVITIES OF HUMAN ARTERIAL TISSUE IN VARIOUS AGE GROUPS.

Age Group (Years)	N	Cholesterol, % of Wet Weight	Mg. beta-naphthylamine lib./Gm. Wet Tissue/Hour	s.d. of distr.	Mg. beta-naphthylamine lib./Gm. Tissue N/Hour	s.d. of distr.
Normal Aortic Tissue						
0 - 0	8	0.2	1.53	0.32	34.9	8.8
10 - 19	5	0.3	1.42	—	32.3	—
20 - 29	5	0.3	1.29	—	27.7	—
30 - 39	12	0.3	1.46	0.31	35.8	7.2
40 - 49	14	0.4	1.45	0.31	39.8	10.6
50 - 59	17	0.5	1.24	0.26	34.0	8.7
60 - 69	13	0.5	1.07	0.27	30.0	7.5
70 - 79	4	0.7	1.52	—	47.0	—
Grand Mean			1.34	0.32	35.0	9.5
Arteriosclerotic Aortic Tissue						
10 - 19	2	0.3	1.90	—	38.7	—
20 - 29	2	0.3	1.43	—	37.2	—
30 - 39	4	0.7	1.54	—	40.2	—
40 - 49	10	0.9	1.29	0.31	40.2	12.7
50 - 59	16	1.1	1.19	0.28	37.6	9.5
60 - 69	11	1.0	1.21	0.55	36.9	20.9
70 - 79	4	1.3	1.66	—	54.6	—
Grand Mean			1.32	0.42	39.6	13.9
Pulmonary Artery Tissue						
0 - 9	7	0.2	1.32	0.38	33.5	10.2
10 - 19	4	0.1	1.43	—	43.7	—
20 - 29	5	0.2	1.56	—	43.3	—
30 - 39	11	0.2	1.43	0.33	39.7	12.2
40 - 49	13	0.2	1.36	0.32	39.7	12.2
50 - 59	17	0.3	1.29	0.27	36.4	8.0
60 - 69	13	0.3	1.10	0.31	33.9	10.8
70 - 79	4	0.3	1.28	—	38.6	—
Grand Mean			1.32	0.34	37.6	11.0
Normal Coronary Artery Tissue						
0 - 9	5	0.1	1.40	—	66.5	—
10 - 19	2	0.1	1.58	—	42.4	—
20 - 29	4	0.2	1.66	—	88.5	—
30 - 39	7	0.3	1.59	0.32	63.8	27.4
40 - 49	8	0.3	1.84	0.36	66.5	18.7
50 - 59	10	0.7	1.47	0.35	56.0	25.2
60 - 69	5	0.4	1.26	—	58.0	—
70 - 79	3	0.4	1.76	—	51.2	—
Grand Mean			1.57	0.41	62.4	26.0
Arteriosclerotic Coronary Artery Tissue						
20 - 29	1	0.4	1.40	—	47.0	—
30 - 39	3	1.3	1.79	—	61.1	—
40 - 49	6	2.4	2.24	0.77	89.0	31.2
50 - 59	9	1.4	1.82	0.68	62.9	21.9
60 - 69	7	1.7	1.62	0.68	65.5	24.4
70 - 79	3	1.7	2.41	—	77.0	—
Grand Mean			1.90	0.66	70.0	25.1

TABLE 2. COEFFICIENTS OF CORRELATION BETWEEN AGE AND LEUCINE AMINOPEPTIDASE ACTIVITIES OF ARTERIAL SAMPLES.

	Wet Tissue		Tissue Nitrogen	
	r	t	r	t
Normal aortic tisue	— 0.28	2.54	+ 0.08	0.69
Pulmonary artery	— 0.23	2.00	— 0.08	0.68
Normal coronary artery tissue	0.00	0.00	— 0.10	0.65

TABLE 3. MEAN LEUCINE AMINOPEPTIDASE ACTIVITIES OF ARTERIOSCLEROTIC TISSUE EXPRESSED IN PERCENTAGE OF ACTIVITIES OF NORMAL TISSUE OF THE SAME ARTERIAL SAMPLES.

Age Group (Years)	N	Wet Tissue		Tissue Nitrogen	
		%	t of diff.	%	t of diff.
Aortic Samples					
30 - 49	14	94	0.56	103	0.44
50 - 59	16	97	0.50	109	1.35
60 - 79	15	109	0.88	118	1.36
30 - 79	45	100	0.00	110	1.85
Coronary Artery Samples					
30 - 79	21	113	1.62	109	0.80

pulmonary artery samples. No variation in enzyme activity with age was observed (table 2), and no statistically significant difference was found between the mean activities of arteriosclerotic and normal portions of the same arteries (table 3).

DISCUSSION

The observed leucine aminopeptidase activity of human aortic tissue is of the same magnitude as that reported by Green and associates (1). This activity is approximately 10 times greater than that exhibited by normal human serum (1).

SUMMARY

Determinations were made of the leucine aminopeptidase activity of 78 samples of the thoracic descending aorta, 74 samples of the pulmonary artery, and 51 samples of the coronary artery obtained from individuals of various ages. The procedure of Green and associates, according to which L-leucyl-beta-naphthylamide hydrochloride is used as substrate for the enzyme, was employed for the activity measurements. In the case of the aortic and coronary artery samples, the enzyme determinations were made separately on normal and arteriosclerotic portions of the same blood vessels.

The average enzyme activities observed for normal aortic, pulmonary artery, and coronary

artery samples, expressed as mg. of beta-naphthylamine liberated/Gm. wet tissue/hour, were respectively, 1.34, 1.32, and 1.57. A moderate tendency was noted for the enzyme activities of the normal aortic and pulmonary artery samples to decrease with age when the values were calculated on the basis of wet tissue weight, but no significant change was recorded when the activities were expressed on the basis of the tissue nitrogen content.

No statistically significant differences were found between the mean leucine aminopeptidase activities of arteriosclerotic and normal tissue portions of the same blood vessels.

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THE GLYOXALASE I ACTIVITY OF ARTERIAL TISSUE IN INDIVIDUALS OF VARIOUS AGES*

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Activity of glyoxalase I, which catalyzes the condensation between methylglyoxal and reduced glutathione, has been demonstrated in various mammalian tissues, but no studies have been reported on the presence of this enzyme in arterial tissue. The present investigation deals with activity measurements of glyoxalase I in human arterial tissue samples obtained fresh at autopsy from subjects of various ages.

MATERIALS AND METHODS

Eighty-six samples of the thoracic descending aorta, 80 samples of the pulmonary artery, and 50 samples of the coronary artery were included in the study. After removal of the adventitia the tissue was rinsed briefly with ice-cold isotonic sodium chloride solution in order to eliminate contamination from adhering blood; for the same reason, only tissue portions which on examination were found to contain no blood capillaries were employed for the studies. In the case of the aortic and coronary artery samples, activity measurements were made both on normal and arteriosclerotic tissue sections of the same blood vessels. Five per cent homogenates were prepared of the intima-media layers by homogenization of the tissue for 2 min. in ice-cold isotonic sodium chloride solution with the use of a Pyrex homogenizer. The homogenates were subsequently centrifuged for 10 min. at 4000 r.p.m., and the supernatants were employed for the activity assays. The determinations were made by a modification of Racker's (3) procedure through spectrophotometric measurement of the rate of formation of the condensation product between methylglyoxal and reduced glutathione.

The methylglyoxal used in the activity measurements was prepared from dihydroxyacetone by hydrolysis with HCl and distillation under reduced pressure. The quantity of methylglyoxal present in the distillate was determined by the dinitrophenylhydrazine method as described previously (2). The absence of measurable quantities of pyruvic acid in the distillate was ascertained by use of the titrimetric procedure of Clift and Cook (1). The glutathione solution employed for the glyoxalase I activity measurements was prepared fresh daily; the pH of the solution was adjusted to 6.6 through addition of sodium hydroxide.

The final millimolar concentrations used in the activity determinations (total volume, 3.05 ml.) were: methylglyoxal, 2.6; reduced glutathione, 2.0; phosphate buffer, pH 6.6, 22.0. An amount of supernatant corresponding to 2.5 mg. of fresh tissue was employed in each test.

The rate of formation of the methylglyoxal-glutathione condensation product was measured at 39 C. by use of a Beckman DU spectrophotometer provided with thermospacer equipment. After preheating of the glutathione-phosphate buffer solution in the cuvette for 3 min., methylglyoxal and the supernatant were added rapidly to the sample with the use of constriction pipettes, and the change in optical density at 240 millimicrons was recorded at intervals of 1 min. over a 7-min. period, the sample being read against a cuvette with distilled water. A reagent blank containing glutathione, methylglyoxal, and phosphate buffer in the same concentrations as used in the test sample was run with each tissue test. The increase in optical density of the reagent blank during the 7-min. period of incubation was quite small, averaging only about 6% of the optical density change of the tissue sample; the increase in optical density in the reagent blank is due to a non-enzymatic combination of methylglyoxal and glutathione.

The molar extinction coefficient of 3370 exhibited by the condensation product formed through catalysis by the tissue glyoxalase I under the reported conditions of measurement (3) was employed for the calculation of the enzyme activity; a correction was made for the disappearance of free glutathione, which shows a molar extinction coefficient of only 72 at 240 millimicrons (3).

The observed K_m for methylglyoxal was 1.2×10^{-3} M and for glutathione 6.7×10^{-4} M. A linear relationship was noted between time of incubation and recorded activity values over the 7-min. period employed in the tests. A high degree of proportionality was also found between the quantity of tissue used and the recorded enzyme activities over a 0.5 to 5.0 mg. tissue range. The completeness of extraction of the enzyme from the arterial tissue by the procedure employed was ascertained in special experiments in which the precipitate obtained after centrifugation of the prepared homogenate was rehomogenized with a new portion of sodium chloride solution. After centrifugation of the second homogenate, the enzyme activity of the resulting supernatant was measured. It was found that only a small activity was present in the second supernatant and that this activity corresponded closely to the value estimated on the basis of the volume and water content of the first residue.

* Studies on Arterial Metabolism 30. The investigation was supported by a grant from the National Institutes of Health, Public Health Service (PHS-891). A preliminary report of this study was published in *J. Lab. & Clin. Med., 52:* 882, 1958 (abstract).

TABLE 1. MEAN GLYOXALASE I ACTIVITIES OF HUMAN ARTERIAL TISSUE IN VARIOUS AGE GROUPS.

Age Group (Years)	N	Cholesterol, % of Wet Weight	mM Methylglyoxal Metab./Gm. Wet Tissue/ Hour	s.d. of distr.
Normal Aortic Tissue				
0 – 9	7	0.1	1.49	0.45
10 – 19	2	0.3	1.72	....
20 – 29	6	0.2	1.28	0.32
30 – 39	11	0.3	1.18	0.44
40 – 49	16	0.4	1.23	0.26
50 – 59	23	0.5	1.03	0.24
60 – 69	17	0.7	1.03	0.29
70 – 79	4	0.5	0.95	....
Grand Mean	..	...	1.19	0.34
Arteriosclerotic Aortic Tissue				
10 – 19	1	0.3	1.60	....
20 – 29	4	0.3	1.14	....
30 – 39	7	0.7	1.23	0.30
40 – 49	13	0.9	1.05	0.34
50 – 59	22	1.1	0.74	0.30
60 – 69	16	1.3	0.74	0.29
70 – 79	4	1.0	0.95	....
Grand Mean	..	...	0.90	0.37
Pulmonary Artery Tissue				
0 – 9	6	0.2	1.73	0.63
10 – 19	1	0.2	1.94	....
20 – 29	5	0.2	1.75	0.68
30 – 39	9	0.2	1.62	0.46
40 – 49	15	0.3	1.46	0.41
50 – 59	23	0.3	1.24	0.32
60 – 69	17	0.3	1.18	0.36
70 – 79	4	0.3	1.02	....
Grand Mean	..	...	1.38	0.50
Normal Coronary Artery Tissue				
0 – 9	3	0.1	1.67	....
10 – 19	1	0.1	1.29	....
20 – 29	3	0.2	0.73	....
30 – 39	4	0.3	1.10	....
40 – 49	12	0.3	1.08	0.35
50 – 59	14	0.7	1.00	0.19
60 – 69	10	0.4	1.00	0.30
70 – 79	3	0.3	1.19	....
Grand Mean	..	...	1.07	0.33
Arteriosclerotic Coronary Artery Tissue				
30 – 39	2	1.0	1.00	....
40 – 49	6	1.6	0.87	0.20
50 – 59	14	1.5	0.78	0.27
60 – 79	10	1.9	0.76	0.38
Grand Mean	..	...	0.79	0.32

RESULTS

The mean glyoxalase I activities of aortic, pulmonary artery, and coronary artery samples observed for various age groups have been listed in table 1.

Aortic samples.—As seen from the data recorded in table 1 a definite tendency was noted for the glyoxalase I activity of the normal aortic tissue to decrease with age. The mean enzyme value observed for the 86 samples included in the study, expressed as millimoles of methylglyoxal metabolized/Gm. wet tissue/hour, was 1.19. The decrease in glyoxalase I activity with age has been illustrated graphically in figure 1. The coefficient of correlation between age and glyoxalase I activity was -0.48 ($t = 5.02$, $N = 86$).

The results of comparisons between the glyoxalase I activities of arteriosclerotic and normal tissue portions of the same blood vessels are listed in table 2. It will be seen from the table that the mean enzyme activity of the arteriosclerotic tissue from aortic samples obtained from individuals aged 50 to 79 years was significantly lower than the average activity of the normal tissue.

Pulmonary artery samples.—In all the age groups investigated (table 1), and in 74% of the individual samples obtained from children

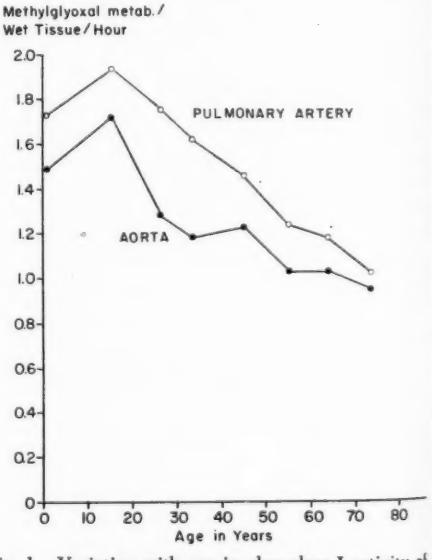

Fig. 1. Variation with age in glyoxalase I activity of normal human aortic tissue and pulmonary artery tissue.

TABLE 2. MEAN GLYOXALASE I ACTIVITIES OF ARTERIOSCLEROTIC TISSUE EXPRESSED IN PERCENTAGE OF ACTIVITIES OF NORMAL TISSUE OF THE SAME ARTERIAL SAMPLES.

Age Group (Years)	N	%	t of diff.
Aortic Samples			
30 - 49	20	91	1.53
50 - 59	22	71	4.35
60 - 79	20	76	3.63
30 - 79	62	79	5.07
Coronary Artery Samples			
30 - 79	32	77	5.05

and adults, the glyoxalase I activity of the pulmonary artery tissue was found to be higher than the activity of the normal aortic tissue. The average value observed for the pulmonary artery samples was 1.38 millimoles of methylglyoxal metabolized/Gm. wet tissue/hour. The tendency of the enzyme activity to decrease with age was similar to that recorded for the aortic tissue (fig. 1), the coefficient of correlation between age and glyoxalase I activity being -0.45 ($t = 4.38$, $N = 80$).

Coronary artery samples.—The average glyoxalase I activity observed for the normal coronary artery tissue samples was 1.07 millimoles of methylglyoxal metabolized/Gm. wet tissue/hour. In 60% of the individual samples examined the enzyme activity of the coronary artery was lower than the activity of the normal aortic tissue; the t value of the difference calculated for the 50 coronary artery samples and the corresponding normal aortic samples was 2.37. In accordance with the observations made on the aortic and pulmonary artery tissue, the glyoxalase I activity of the coronary artery samples was found to decrease with age; the decrease, however, was not statistically significant ($r = -0.27$, $t = 1.94$, $N = 50$).

As seen from table 2 the mean activity of the arteriosclerotic coronary artery portions was notably lower than the average activity of the normal tissue.

SUMMARY

Determinations were made of the glyoxalase I activity of 86 samples of the thoracic descending aorta, 80 samples of the pulmonary artery, and 50 samples of the coronary artery obtained from individuals of various ages. A modification of Racker's procedure was employed for the activity assays. In the case of the aortic and coronary artery samples, the enzyme measurements were made separately on normal and arteriosclerotic portions of the same blood vessels.

The mean enzyme activities of normal aortic, pulmonary artery, and normal coronary artery samples, expressed as millimoles of methylglyoxal metabolized/Gm. wet tissue/hour, were, respectively, 1.19, 1.38, and 1.07. The glyoxalase I activity of the arterial tissue showed a definite tendency to decrease with age, the coefficient of correlation between age and enzyme activity being -0.48 ($t = 5.02$) for the aortic tissue, -0.45 ($t = 4.38$) for the pulmonary artery tissue, and $-.27$ ($t = 1.94$) for the coronary artery tissue. The average glyoxalase I activities of arteriosclerotic tissue portions of the aorta and coronary artery were found to be significantly lower than the mean activities of the normal tissue sections.

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MICROMORPHOLOGICAL DATA ON AGING BONE ATROPHY AS SEEN IN MICRORADIOGRAPHS AND COLORED SPECIMENS

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During the last 80 years, several points of view have been presented with regard to the morphology and the mechanism of calcium deficiency in bone. These views are controversial in many respects.

Kölliker (10) and, more recently, Albright (1) and McLean (14, 15) have advanced an hypothesis which may be called the osteoclast theory. According to these authors, any resorptive process in bone, including bone atrophy or osteoporosis, must first pass through a stage during which both organic and inorganic bone constituents are destroyed. It is assumed that the osteoclasts are chiefly responsible for this bone destruction. Kroon (11) believes that osteoclasts produce a bone-dissolving enzyme. This dissolution is indicated by a brush border on the bone periphery, usually near osteoclasts.

It has been observed that resorptive processes in bone may proceed without demonstrable osteoclasts (13, 18). One example is the local bone atrophy where there is constant pressure on bone, e.g., by an aneurysm or tumor. Another example is the resorption caused by a rapidly growing bone tumor. It has also been found in animal experiments and in observations in humans that the turnover between bone calcium and body fluids proceeds in many cases so rapidly that the possibility of the participation of osteoclasts in this process is very doubtful (2, 9, 12).

Another mechanism for the calcium impoverishment of bone is halisteresis, a term proposed by Kilian (16). It is believed that in this process, bone undergoes changes similar to the artificial decalcification used in histological practice. In other words, calcium only is supposed to leave bone in halisteresis, all other constituents of bone remaining. However suitable the halisteresis theory seems to be for the explanation of many obscure facts of exchange between bone calcium and body fluids, advocates of this theory were unable with methods then in use to demonstrate any positive morphological proof for its support. The presentation of positive morphological evidence on behalf of halisteresis as a principal mechanism of calcium loss by normal aging bone is one aim of this work; the other being the description of micromorphology of atrophic aging bone as seen with new methods.

MATERIAL AND METHODS

Bones of 20 skeletons of aged persons 70 years and older, of both sexes, were obtained from the Department of Anatomy, University of Ottawa, and from the Ottawa General Hospital.

Approximately 1,000 serial microradiographs and 350 colored specimens of aging bones were used in the present study. Specimens of 5 skeletons of younger persons (9, 22, 27, 32, and 48 years old), comprising about 300 microradiographs and colored specimens were prepared for comparison. Vertebral bodies were chosen for the study of bone atrophy because here compact bone and spongy bone are well represented. Bones were taken from persons who died from causes which had no apparent relation to their skeletons.

New techniques of serial bone sectioning with the following contact microradiography (6) and stain historadiography (5) were used in

All figures are reproductions of original microradiographs. The maximum white color corresponds to the abundance of calcium, black represents the absence of calcium.

Fig. 1. MRD (microradiograph) of 10 μ section. Age—77. × 180. Brittleness of aging bone. Transversal calcified fibers are seen in rarefied strata.

Fig. 2. MRD, 5 μ, age—28. × 180. The elasticity of young bone. Stratification is well expressed.

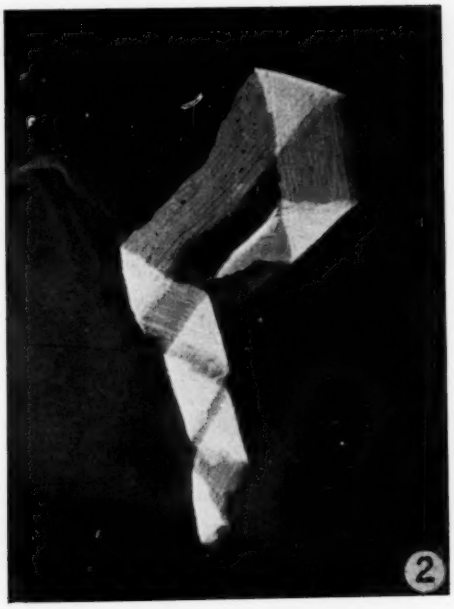
Fig. 3. MRD, 10 μ, age—91. × 90. Compare with next figure.

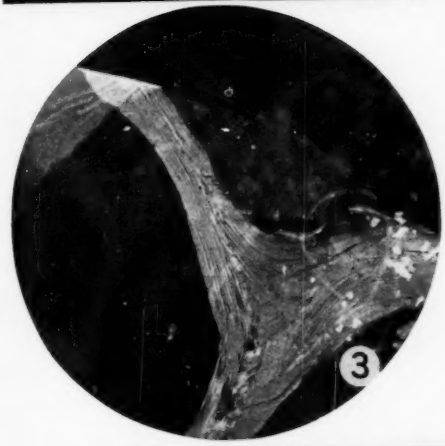
Fig. 4. MRD, 10 μ, age—22. × 90. Technical conditions of microradiography in figs. 3 and 4 are identical. Young bone contains much more calcium than the atrophic old bone. It is revealed in whiter color of image of young bone.

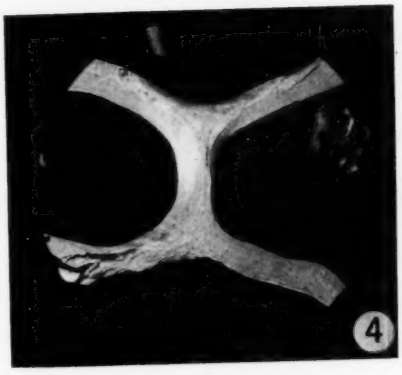
Fig. 5. MRD of isolated bundle of atrophic fibers. Age—79. × 300. Stratification is almost absent. Irregularity in calcium denudation of atrophic fibers (remnants of calcium are seen as white specks).

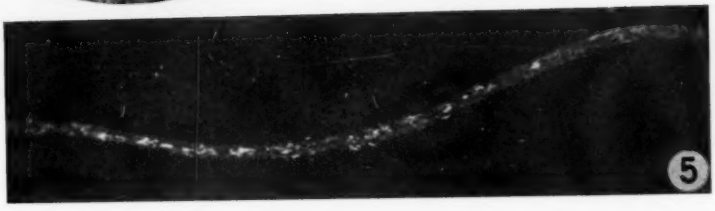
This work is part of a study on Bone Aging which was started with grants from the Atkinson Charitable Foundation and the Canadian Arthritis and Rheumatism Society and is now continued with the support of Research Grant # A-2298 of the Department of Health, Education, and Welfare, U. S. Public Health Service.

The author is indebted to Dr. J. Auer, Dr. P. Harker and Dr. R. Mitchell for their help in the preparation of this manuscript.









this work. All the details of theory and new technique have been described either in these publications or in works on microradiography (3, 4, 7, 8, 17).

After short fixation, undecalcified bones, in some cases together with adjacent soft tissues, were embedded in Ward's bio-plastic. Prepared blocks were then cut into sections of appropriate thickness with a special bone microtome (Jung Co., Heidelberg, Germany). Sections 10 μ thick were mostly used in this work and first radiographed with soft X-rays (8-12 kv.). Radiography was carried out on a fine-grain emulsion, usually Eastman Kodak 649-0 or GH spectroscopic plates. Most of the sections were subjected to coloring procedures after microradiography (the term coloring instead of staining is used after Baker).

Colored specimens and their microradiographs were mounted together on a glass slide and studied alternately under the microscope. The maximum magnification used was $\times$ 300, the working magnification $\times$ 120-150. The distribution of calcium in bone elements was studied in microradiographs; interrelations between tissues containing calcium and those free of it were observed in colored specimens.

RESULTS

All figures shown are reproductions of original microradiographs; consequently, the maximum white color of the image corresponds to the maximum absorption of X-rays. Bone is always shown as white or varying shades of gray (the latter in microradiographs of atrophic bone). Soft tissues appear black or dark gray.

Microradiographs of sections 10 μ and thinner of vertebrae or other fine-fibered bones always reveal many strata coursing parallel to each other (6, 18) (figs. 2, 3). If bone is artificially parted asunder (e.g., during cutting) the calcified fibers or their bundles become conspicuous. The neighboring strata absorb X-rays differently; those absorbing more are called opaque strata. Such a stratum consists apparently of calcified fibers coursing parallel to each other. Another stratum absorbs X-ray less and is therefore called rarefied stratum. It consists of thin calcified fibers crossing trabecula perpendicular or oblique to its long axis (figs. 1, 10) and probably also of calcified ground substance. In osteons calcified fibers of rarefied strata spread radially from the centre which is occupied by a Haversian canal (6).

In accordance with findings reported below, the term aging bone atrophy is used in this work for the definition of calcium deficiency in bones of normal old persons. The term osteoporosis is herewith proposed to be used for cases of pathological calcium loss accompanied with the destruction of organic and mineral bone matrix.

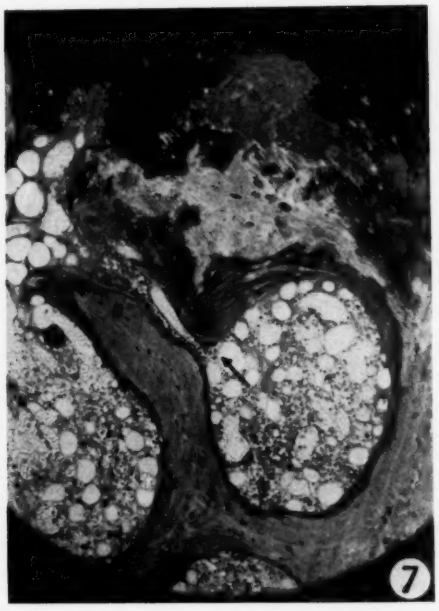
Signs of Aging Bone Atrophy as Seen in Microradiographs and Colored Specimens

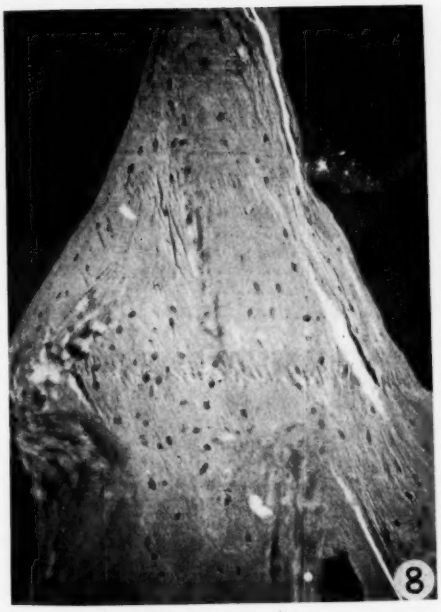
1. Calcium impoverishment of normal aging atrophic bone is revealed in microradiographs even at low power as an increase of blackness due to the greater X-ray transparency of atrophic bone (figs. 3, 4). This sign was found in approximately 75% of skeletons of all normal persons in the seventh decade, but in the eighth and ninth decades, it was conspicuous in all cases observed by us. However, mindful of many individual variations and of possible mistakes in technique, the author does not consider only the increase in X-ray transparency to be a decisive sign of bone atrophy. For this reason this diagnosis is certain only when morphological changes, typical of this bone condition, are also present.

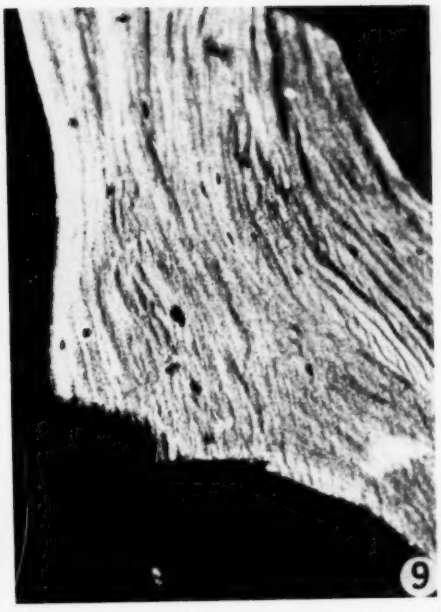
2. Initial morphological signs of aging bone atrophy have been found in calcified fibers of opaque strata. These strata, if separated, have a mottled appearance in aging bone (fig. 5, 8). While in a calcified fiber of adult bone calcium crystals or groups of them are placed more or less symmetrically in definite intervals along the fiber, in atrophic bone large areas of the fiber are denuded of calcium. These irregularities in calcium impregnation become visible in atrophic bone even within the limits of magnification of microradiographs.

3. Comparison of a colored specimen of aging atrophic bone with its microradiograph reveals some areas adjacent to or between trabeculae in which only connective tissue (probably collagen fibers) is present, and calcium is not visible (figs. 6, 7). Fibers of this tissue have a very similar appearance to calcified fibers of opaque strata. In some microradiographs, one could observe the exact continuation of a calcified fiber into a non-calcified one.

4. As a rule neither in atrophic compact bone nor in atrophic trabeculae is the massing of cells resembling osteoclasts noticeable, although single cells of such kind were frequently seen in specimens colored with dyes used in this work: Safranin-O - Fast Green (Böhm-Oppel) or Thionine - Picric Acid (Schmorl).





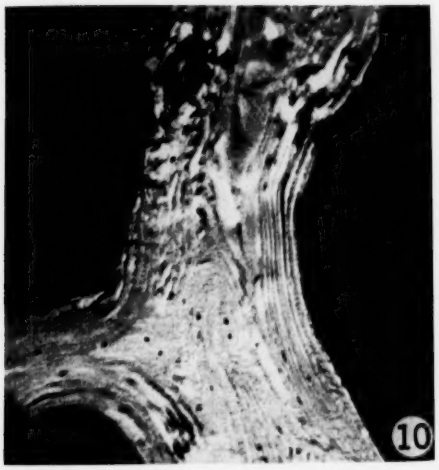


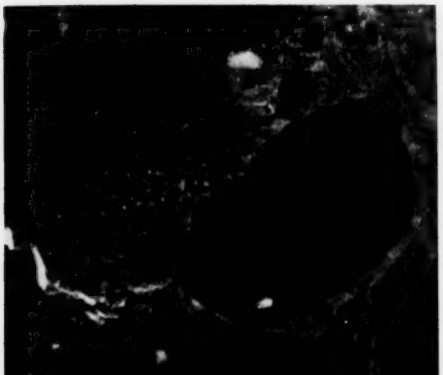
All figures are reproductions of original microradiographs. The maximum white color corresponds to the abundance of calcium, black represents the absence of calcium.

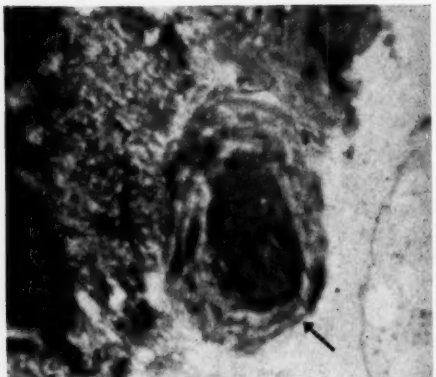
Fig. 6. MRD, Fig. 7. Colored specimen, 10 μ, age—72. Both × 160. Decalcified fibers are seen which surround remnants of calcified tissue.

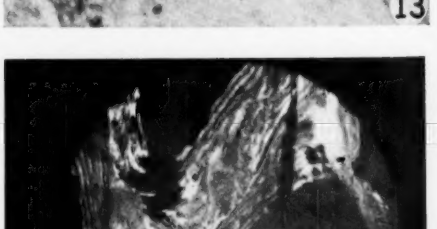
Fig. 8. MRD, 10 μ, age—82. × 200. Enlarged, irregular intraosseous lacunae.

Fig. 9. MRD (approx. 7 kv.), 10 μ, age—91. × 240. Mottled appearance at atrophic fibers is especially demonstrative in left lower corner of bone image.









All figures are reproductions of original microradiographs. The maximum white color corresponds to the abundance of calcium, black represents the absence of calcium.

Fig. 10. MRD, 10 μ, age—78. × 200. Increased stratification of atrophic bone. The structure of rarefied strata is conspicuous.,

Fig. 11. MRD, 10 μ, age—78. × 180. Brush border in medial upper part of bone image.

Fig. 12. MRD, Fig. 13. Colored specimen, 10 μ, age—74. × 240. Calcified dots in left upper corner of both pictures. The arrows indicate that the big black hole present in MRD is much smaller in the colored specimen. Stratification of calcium-free fibers within the hole is conspicuous.

Fig. 14. MRD, 10 μ, age—27. × 120. Bone artificially decalcified.

5. Enlargement of intraosseous lacunae, which are mostly situated in rarefied strata, is the first indication of calcium loss by this stratum. This finding was reported in previous work (4). Instead of the usual 5 to 15 μ average two-dimensional measure, twice as large lacunae are frequently present in atrophic bone (fig. 9). One may observe that some lacunae have round or irregular outlines instead of the spindle-like shape typical of adult bone. It is found later on after the introduction of coloring method (5) that osteocytes are present in some of these lacunae, whereas other lacunae are empty.

6. The stratified appearance of aging atrophic bone is always conspicuous and even more pronounced (figs. 3, 10). The presence of this stratification is an indirect sign of calcium loss by the rarefied stratum. If only the opaque stratum loses its calcium and the rarefied stratum does not, then the calcium content as well as the X-ray absorption will be equalized in both strata in course of the atrophic process with the resulting disappearance of difference in their contrasts.

7. In a subchondral zone of aging atrophic bone, remnants of calcium are sometimes observed as small grains or dots (fig. 12). No osteoclasts are observed in these areas. Dots are conspicuous all over the organic matrix which is not destroyed (fig. 13).

8. Atrophic decalcification of strata around any bone canals results in an appearance of big black holes in bone tissue. Colored specimens show, however, that the internal part of these holes is filled up with calcium-free collagen fibers, preserving their stratigraphic course (figs. 12, 13).

9. A finding similar to a brush border as described by many authors has been observed in several microradiographs of aging atrophic bone (fig. 11). Such a comb-like margin is mostly present on the periphery of trabeculae of bone fragments. Probably teeth of the comb represent calcified fibers split by the cutting knife. It is necessary to mention here that no massing of osteoclast-like cells near this border has been found by the author.

10. It is known that the atrophic bone is sometimes very brittle. Microradiographs in this case demonstrate many small fragments of bone after cutting (fig. 1). Section of elastic young bone is given for comparison (fig. 2).

It is appropriate to mention here that in the case of incomplete artificial decalcification, the microradiographical image of a partially decalcified fiber is very similar to that seen in an advanced aging bone atrophy (fig. 14). Such a partial decalcification can be achieved through the immersion of bone sections in a weak solution of hydrochloric acid (0.43%) for 11-14 sec.

SUMMARY

Bones from apparently healthy old persons studied in 1,000 microradiographs and 350 colored specimens presented several signs of calcium deficiency in various bone elements. Some of these signs indicate that the impoverishment of bone with calcium develops in old age mainly through halisteresis. In accordance with the latter finding, this loss of calcium by normal aging bone is called aging bone atrophy. The term osteoporosis is proposed to be used in pathological cases.

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DARK ADAPTATION AS A FUNCTION OF AGE: I. A STATISTICAL ANALYSIS

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A. BERTRAND WARREN, Ph.D., AND DAVID C. WARD, B.A.
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The purpose of this paper is to make a detailed statistical study and interpretation of the relationship between dark adaptation and age. Several studies (1, 3, 4, 7, 10, 12, 13, 16, 20, 21) have demonstrated a relationship between age and the process of dark adaptation, but an attempt to estimate the extent of the changes in the general population from the existing data has proved almost impossible. This is true partly because the experimental conditions, degree and time of presentation, intensity, and color of light under which this phenomenon has been studied have varied widely from one age sample to another and partly because those studies that have shown a relationship have depended upon highly select samples that did not represent the general population (16). Such experimental groups have varied in both composition and size. Furthermore, in some studies an artificial pupil (16) or a mydriatic (14) was used, and in others they were not (7). However, the indications are that the range of individual differences in the dark adaptation process as a function of age is considerably greater than has previously been supposed, and greater than any one study has demonstrated. Therefore, to obtain a better estimate of the influence age has upon the dark adaptation process the present study was conducted using a much larger and more representative age sample of the population.

The dark adaptation process takes place in two distinct phases. Figure 1 indicates that when the level of luminance is suddenly reduced the first phase is relatively short and is usually completed within the first 6-8 minutes. The junction of the first segment curve with the second segment curve represents near cessation of cone vision. At this point rod vision is initiated at a relatively fast rate as represented by the lower of the two curves. The rod vision curve nearly reaches its lowest point in an additional 20-30 minutes. Both curves, the rate at which they develop, and the point at which they intersect are of considerable interest, theoretically and practically (6).

Among those variables which influence rate and the ultimate degree to which the viewer will be able to adapt at low levels of luminance are duration and intensity of pre-exposure illumination (5, 19), and wave length (8, 24).

The variables taken into consideration in the present study were (a) age, (b) dark adaptation thresholds for 21 time intervals, and (c) the intersection of the cone and rod curves.

METHOD

Subjects.—There were 240 male subjects. Thirty subjects were drawn from each decade ranging from the teen-age level through the age of 89 years. The total sample was composed of persons taken from YMCA groups, college-age students, university faculty, taxi drivers, unemployed persons obtained from the USES Agency, and retired men living at home or in private institutions for the aged. All subjects were paid for their services, and subsequent to obtaining the data, over half the subjects in each decade were then offered and given a complete eye examination free of charge.

Apparatus.—The instrument (10) used throughout this study was the Hecht-Schlaer Adaptometer which had been rebuilt and recalibrated by the manufacturer (O. C. Rudolph and Sons, Caldwell, New Jersey, Model No. 1, Serial No. 14). The research was conducted in three different cities in order to accommodate aged persons for whom travelling was difficult.

Procedure.—After each subject was seated in the experimental room, his left eye was covered by a patch, and his head was held steady in a head-chin rest. Vision was uncorrected. The lights in the dark room were turned off, and after a lapse of approximately one minute, the retina of the right eye was bleached by exposure to a standard 1600 millilamberts incandescent light source for 3 minutes. At the end of the pre-test period, the subject was exposed to a red fixation point 7 degrees right of center. The violet light test stimulus of 1 degree

Sponsored by the Commission on Accidental Trauma of the Armed Forces Epidemiological Board and supported in part by the Office of the Surgeon General, Department of the Army.

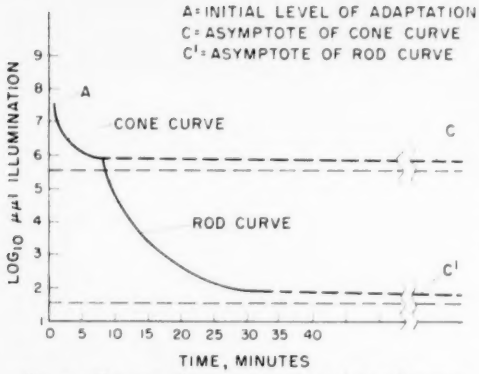

Fig. 1. The two phases of a typical dark adaptation curve in relation to time and level of luminance.

(53.0% transmission at 405 μ) was then presented. The duration of each flash of light was 1/5 of a second. All of the experimental observations were made by the same person (David C. Ward).

The first observation was made within the first 59 seconds after the termination of the preexposure light. Then, beginning with the second observation, one reading was taken every minute for the next 9 minutes, every 2 minutes for the next 6 minutes, and every 3 minutes for the following 24 minutes.

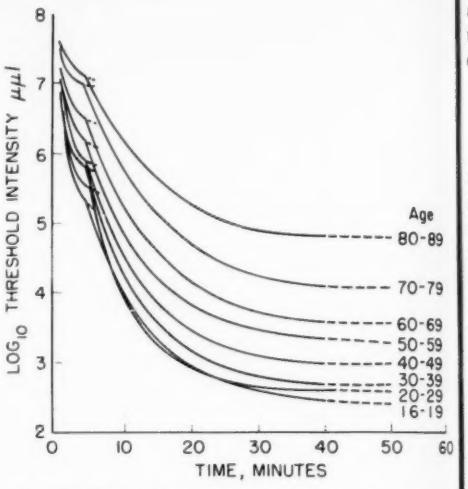

Fig. 2. Dark adaptation as a function of age. Age range 16-89 years, N = 240.

RESULTS

Table 1 and figure 2 reveal that the family of mean dark adaptation curves obtained as a function of age rises in an orderly manner, suggesting that the differences between their terminal points increases geometrically from one

TABLE 1. MEAN DARK ADAPTATION AS A FUNCTION OF AGE AND TIME LOG_{10} $\mu\mu$l LUMINANCE.*

Age (Years)	16–19		20–29		30–39		40–49		50–59		60–69		70–79		80–89	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
0–59 Sec.	6.93	.30	6.78	.41	6.95	.32	7.03	.26	7.06	.26	7.21	.24	7.49	.58	7.67	.13
Min.																
2	6.42	.32	6.16	.46	6.37	.34	6.62	.27	6.78	.27	6.94	.25	7.16	.57	7.43	.14
3	5.93	.39	5.65	.48	6.05	.35	6.29	.32	6.49	.31	6.73	.31	7.06	.17	7.25	.15
4	5.66	.39	5.43	.51	5.85	.40	5.98	.35	6.25	.40	6.59	.34	6.95	.22	7.12	.16
5	5.58	.40	5.26	.60	5.67	.47	5.86	.37	6.17	.42	6.50	.43	6.94	.23	7.08	.17
6	5.36	.41	5.05	.67	5.45	.48	5.61	.33	5.94	.46	6.27	.38	6.70	.29	6.90	.21
7	5.08	.45	4.83	.71	5.17	.46	5.36	.34	5.63	.44	6.02	.38	6.48	.29	6.71	.26
8	4.82	.46	4.61	.66	4.86	.47	5.10	.38	5.41	.45	5.76	.44	6.25	.32	6.52	.29
9	4.55	.52	4.38	.66	4.84	.38	4.80	.38	5.14	.50	5.51	.51	5.98	.43	6.33	.43
10	4.17	.48	3.95	.63	4.17	.36	4.51	.39	4.77	.60	5.24	.65	5.71	.44	6.10	.45
12	3.80	.40	3.50	.46	3.87	.38	4.22	.34	4.48	.64	4.99	.61	5.48	.46	5.91	.50
14	3.48	.43	3.28	.47	3.62	.37	3.96	.35	4.25	.61	4.78	.61	5.26	.45	5.74	.55
16	3.24	.41	3.14	.47	3.44	.37	3.76	.31	4.02	.57	4.50	.59	5.00	.48	5.55	.59
19	3.02	.35	2.98	.45	3.23	.37	3.54	.31	3.85	.57	4.27	.59	4.74	.48	5.54	.59
22	2.86	.35	8.85	.45	3.04	.29	3.34	.29	3.70	.58	4.05	.55	4.54	.47	5.16	.62
25	2.74	.32	2.78	.45	2.93	.30	3.22	.29	3.55	.53	3.88	.53	4.36	.46	5.01	.66
28	2.64	.30	2.72	.46	2.87	.27	3.13	.30	3.43	.51	3.74	.52	4.22	.46	4.90	.68
31	2.52	.30	2.65	.47	2.81	.28	3.07	.31	3.36	.48	3.67	.50	4.14	.47	4.83	.71
34	2.45	.23	2.64	.47	2.77	.26	3.02	.29	3.32	.47	3.63	.49	4.11	.47	4.81	.72
37	2.43	.17	2.60	.46	2.76	.25	3.02	.29	3.32	.47	3.62	.48	4.11	.48	4.81	.73
40	2.43	.17	2.60	.44	2.76	.26	3.02	.29	3.32	.47	3.62	.48	4.11	.48	4.81	.72

* The data for 0-59 seconds were not used in the statistical analysis since they were considered the least reliable.

age level to the next. Table 1 also shows that the standard deviation for each threshold is exceedingly small.

A. *The Determination of the Cone-Rod Transition Point.*

In order to describe the statistical interrelationship of cone to rod thresholds, it was first necessary to identify the point of transition between the two types of curves. To accomplish this, an attempt was made to fit the cone and rod data separately for each of 240 subjects. However, in this sample vision was uncorrected, and no one equation could be found that would fit all the individual curves simultaneously because of the range of individual differences. Therefore, all the data in each decade were averaged. The results were the highly uniform mean curves shown in figure 2.

Then the negative exponential cone curves and rod curves were converted to straight line plots by a triple $\log_{10}$ transformation of the micromicrolamberts ($\mu\mu$l) luminance data plotted against $\log_{10}$ time. It seems that there is a natural separation of the data between the 5th and 6th minute for all 8 curves, indicating that transition time was independent of age. However, a mathematical method for determining more exactly the separation point of the mean cone and mean rod curves was devised.

There were 21 values for each mean curve. The dark adaptation thresholds, at the 0-59 second interval, and at minutes 2, 3, 4, 5, 6, 7, 10, 16, 22, 28, and 40, elapsed time from zero minutes, were used in this procedure. With the method of residuals (23) least squares fit was determined for the first 3 and the last 9 values in each of the curves, then for the first 4 and the last 8 values, and so on, until several different pairs of distributions for each of the mean curves had been tested. Those pairs having the smallest least squares value defined the transition point between cone and rod vision. For instance, it was found that residuals were least when the first 5 and the last 7 points fitted a pair of straight lines better than the first 4 and the last several points. This indicated that the slope formed by the first 5 scores changed direction between the 5th and 6th minutes therefore identifying the transition point between cone and rod thresholds. Hereafter, dark adaptation thresholds at the 5th minute will be considered the last obtained values for cones. The thresholds at the 6th minute will be considered the first obtained values for rods.

B. *The Determination of Age and Dark Adaptation Threshold Intercorrelations.*

In the second step of the analysis the age of the subjects was correlated with the dark adaptation thresholds distributed in time from 2 to 40 minutes.

Then the dark adaptation thresholds at each time interval were correlated with all other

TABLE 2. INTERCORRELATION OF DARK ADAPTATION THRESHOLDS FOR EACH TIME INTERVAL AND DARK ADAPTATION THRESHOLDS WITH AGE.*

N 240—Age Range 16-89 Years

Min.	2	3	4	5	6	7	8	9	10	12	14	16	19	22	25	28	31	34	37	40	Age
2		.87	.83	.83	.81	.79	.77	.76	.76	.75	.75	.74	.73	.73	.71	.70	.69	.69	.70	.70	.71
3			.96	.96	.94	.92	.90	.88	.87	.86	.85	.84	.82	.82	.81	.79	.79	.79	.79	.79	.82
4				.98	.97	.94	.92	.90	.89	.88	.87	.85	.84	.83	.82	.80	.79	.79	.80	.80	.80
5					.98	.95	.93	.91	.89	.88	.86	.85	.83	.83	.81	.79	.79	.78	.79	.79	.80
6						.97	.95	.93	.91	.90	.89	.87	.85	.85	.83	.82	.81	.81	.80	.81	.79
7							.98	.96	.93	.92	.91	.89	.87	.86	.86	.83	.82	.82	.82	.82	.79
8								.99	.95	.93	.92	.91	.89	.88	.87	.85	.84	.83	.83	.83	.79
9									.96	.95	.94	.93	.90	.89	.89	.87	.86	.85	.84	.85	.79
10										.97	.96	.95	.93	.91	.91	.89	.88	.87	.87	.87	.79
12											.98	.97	.96	.94	.93	.92	.91	.90	.90	.90	.82
14												.99	.98	.96	.95	.94	.92	.92	.91	.92	.84
16													.99	.98	.96	.96	.94	.93	.93	.93	.83
19														.99	.98	.97	.96	.95	.95	.95	.83
22															.99	.98	.97	.97	.97	.97	.83
28																.99	.98	.98	.98	.98	.83
28																	.99	.99	.99	.99	.82
31																		.99	.99	.99	.82
34																			.99	.99	.83
37																				.99	.84
40																					.84

*To be significant at the 0.01 level of confidence r should be 0.155. All the obtained correlations exceeded this value.

thresholds at all other time intervals. The results are shown in the correlation matrix in table 2.

1. *The Correlation of Age with Dark Adaptation Thresholds at Each Time Interval.*

Age is shown to be highly correlated with dark adaptation thresholds at all time intervals from 2 through 40 minutes. Correlations between thresholds and age ranged from 0.71 at the 2nd minute to 0.84 at the 40th minute of dark adaptation. In general the correlation between age and threshold increased as time in the dark increased. However, since the correlation values from the 3rd through the 40th minute were homogeneous, age was correlated equally well with any dark adaptation threshold except at the 2nd minute.

2. *The Intercorrelation of Dark Adaptation Thresholds.*

The correlation between the initial dark adaptation thresholds obtained during the second minute with the last obtained cone thresholds at the 5th minute was 0.83, a highly significant relationship.

The last obtained cone thresholds at the 5th minute correlated 0.79 with the last obtained thresholds for rods at the 40th minute, a highly significant relationship.

The correlation between cone thresholds at the 2nd minute and the rod thresholds at the 40th minute was 0.70, a highly significant relationship.

In general all cone and rod thresholds were highly correlated among themselves and were also highly correlated with age. Many other combinations of age-threshold-time relationships not described in this text may be read directly from table 2.

DISCUSSION

Systematic data describing the decline of dark adaptation with age should provide one kind of index representing the aging process. For instance it has been shown that the efficiency of dark adaptation varies as a function of anoxia (14), CO concentration (18), hypoglycemia (15), and vitamin A deficiency (8, 9, 13). This evidence suggests that metabolism in the retina may resemble metabolism in the central nervous system. Thus, because the central nervous system depends upon the oxidation of blood sugar, any reduction of this substance would decrease the rate of oxidation. In a parallel manner the aging process is thought to be associated with a progressive decrease in rate, amount, or other aspects of cerebral circulation and, therefore, interference with the transport or utilization of oxygen (16). It would follow, all else being equal, that as age increases there would be a progressive increase in the demand for light. Therefore, since aging is universal, considerable variation of dark adaptation efficiency is to be expected in the general population.

Those authors who have studied the relationship between age and dark adaptation or efficiency of night vision are not all in agreement with respect to the degree of the correlation (21), nor are all in accord concerning the significance of the association of aging and the process of dark adaptation. An anonymous author (2) reported negative correlations which ranged between -0.25 and -0.31. Other results have been reported by Birren, Bick, and Fox (3), McFarland and Fisher (16), Liljencrantz (12), Birren and Shock (4), Ives, Shilling, and Curley (11), Robertson (21), and Pinson (20). Pinson, however, stated that the relationship, although positive, was less than the range of individual differences and of minor significance. On the other hand, McFarland and Fisher (16), having obtained one of the highest correlations among physiological phenomena, state that the linear correlation is so high that it may be used to predict level of dark adaptation within the narrow limits of error.

Turning from theoretical consideration to the matter of interpreting these data the question of significance presents itself. The group was heterogeneous, and the results obtained suggest that the aging process introduced a very large decrement into these data. The mean value at the 40th minute of adaptation for the 80-89 year group was $\log_{10}$ $\mu\mu$l I 4.805 (antilog. equal to approximately 63,830), and the level of dark adaptation at the same time for teenagers between 16-19 years of age was 2.427 (antilog. approximately equal to 267). This means that on the average the just noticeable light stimulus for the elderly group was 63,830/267, or approximately 239 times greater than the least stimulus noticed by teenagers after each group had nearly reached the 40th minute of adaptation. It would be expected that the difference between the first values obtained at 0-59 seconds would not be as great. This proved to be correct. For the youngest group the $\log_{10}$ $\mu\mu$l value for the first score

was 6.929 (antilog. approximately equal to 8,490,000) and the value for the elderly group was 7.617 (antilog. approximately equal to 41,400,000). Thus, 41,400,000/8,490,000 is equal to a factor of about 4.88. Even at that moment immediately following the pre-exposure period teenagers, on the average, were able to perceive a just noticeable stimulus about 5 times less bright than were the average persons in the elderly group. Since these values were obtained from the means of the dark adaptation curves there were subjects in the younger group who fell below their mean, and subjects in the oldest group who fell above their mean. Therefore, the absolute differences between the most and the least efficient persons in the entire sample would be larger than the values indicated above.

It can be seen in figure 2 that although the intersections of the cone and rod curves are independent of age because they all appear at approximately the same time they are not identical with respect to level of luminance present at the time the curves separate. It should be pointed out that the concept of a certain level of luminance above which cones function and below which rods function is valid only with respect to an individual dark adaptation curve. For instance, it is generally accepted that 0.01 millilamberts is the approximate degree of luminance at which cone and rod vision separate. But this does not represent the population at all. As a matter of fact in this study the approximate mean time at which the two curves separated was the 5th-6th minute of adaptation. But the mean level of luminance varied from 5.26 $\log_{10}$ $\mu\mu$l I for the 20-29 age group, to 7.075 $\log_{10}$ $\mu\mu$l I for the 80-89 age group at the intersection of the cone and rod curves for those two groups as shown in table 1.

Another way of interpreting these data would be to compare the relative dark adaptation thresholds of the various age groups at different times. For instance, it requires 40 minutes for the most elderly group to develop the equivalent sensitivity characteristic of the youngest group at the 6-7th minute of adaptation. And dark adaptation at the 6-7th minute of adaptation is very limited regardless of the age of the viewer. In other words, youths achieve in 6 to 7 minutes of dark adaptation a level of sensitivity that is not reached by elderly persons in more than 6 times that amount of time. Even at the average age of 55 at the 40th minute of adaptation the viewer has no greater dark adaptation threshold than youths 16-29 years of age at the 15th minute of adaptation, some time before the final level of adaptation is approximated.

It is unlikely that either youths or elderly persons enter upon tasks demanding the degree of sensitivity characteristic of their ultimate level of dark adaptation. There is little to be seen under the levels of luminance as low as between 2 and 5 $\log_{10}$ $\mu\mu$l I, except, of course, the perception of some light source itself. In some military operations (2, 7, 11, 12, 20) such as night watch, dark adaptation is important for exactly this reason. Otherwise the viewer could function as well in total darkness for which no adaptation is necessary.

There are, however, other kinds of situations which may, by and large, be just as important and perhaps more so because of their ubiquity. Thus, old and young alike undertake tasks that require partial adaptation, for instance, the operation of transport equipment at night (1, 13, 17) under the conditions of intermittent, unpredictable changes of luminance. The range of luminance is quite great, and high enough to prevent a final level of adaptation. Generally the illumination changes characteristic of the driving task are large enough to involve both the rod and cone cells of the retina. Therefore, the continuous process of bleaching and adaptation of the retina means that crossing over from rod to cone vision and vice versa is a common event. Rate of adaptation now becomes exceedingly important. But it is precisely in this region that certain types of inefficiency arise. The terminal level of adaptation of the cone cells almost defines the moment when 3 dimensional vision, acuity, and color vision become greatly limited, and the moment before the rod cells have generated any useful degree of sensitivity.

It is suggested that these data have practical applications. For instance, since age is so highly correlated with all dark adaptation thresholds, and since all dark adaptation thresholds are highly intercorrelated, the development of a short clinical test of dark adaptation is entirely feasible. Thus, the first few minutes of dark adaptation predicts dark adaptation thresholds remote in time.

If these data are interpreted as baseline data for the age group and the experimental conditions under which they were obtained, then estimates of probable dark adaptation thresholds may be calculated directly from tables 1 and 2.

For instance, the probable 40th minute threshold of dark adaptation for an individual 85 years of age is shown in table 1 in the last column and the last row to be 4.81 $\log_{10}$ $\mu\mu$l plus or minus 0.72. For a youth age 19.7 years a comparable level of dark adaptation sensitivity at the 40th minute is shown in the first column and last row to be 2.43 $\log_{10}$ $\mu\mu$l plus or minus 0.17. The difference between the two individuals is statistically significant beyond the 0.001 level of confidence.

SUMMARY

From a study of 240 male subjects (age range 16-89 years) it was determined that age is highly correlated with all dark adaptation thresholds which in turn are highly intercorrelated; the correlation between age and dark adaptation thresholds tends to increase as time in the dark increases; cone and rod thresholds are highly correlated; and the reduction in thresholds of dark adaptation in relation to age is very marked.

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AGE DIFFERENCES IN RESIDUAL LUNG VOLUME AND VITAL CAPACITY OF NORMAL INDIVIDUALS*

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Age changes in pulmonary spaces are of interest from several points of view. The basic facts concerning the onset and the rate of these changes are relevant for gerontology, and the clinician must take into account the alterations in the relative value of the volume of the residual air so as not to misinterpret the normal increase in this compartment, observed in the course of aging, and symptoms of specific pulmonary pathology.

The present paper relates the problem to studies on changes in body composition with age (5). In the course of these studies it was necessary to assess the volume of gas present in the lungs and respiratory dead space for the purpose of correcting body volume. This information is needed in calculating body density, used for the estimation of total fat in the body (13). In the absence of direct measurements, the value of 1.45 to 1.50 L. is an appropriate approximate correction for residual volume (RV) of groups of young men (4, 18). In view of the fact that residual volume increases with age, using the same correction value throughout the adult age span would lower the density of the older individuals and, consequently, raise the estimated value of body fat. In the present communication we report data on the residual volume of young and middle-aged men, examined both under ordinary room conditions and during underwater weighing, and of women weighed under water.

METHODS

Measurement of residual volume was made by the open circuit method (9) in air or in connection with determination of body volume by submersion (6). In the in-air studies the method was modified to include a secondary circuit for measurement of vital capacity; this was inserted into the main circuit near the respiratory valve connection of the mouth piece. The measurements were made in an air-conditioned room (78 F., 40-50% relative saturation) with the subjects sitting in a chair, following a 15 min. rest. The vital capacity measurements were made after 3 or 4 preliminary trials, following which the residual volume was determined. During 7 min. the subject inhaled pure oxygen; the expired gases were collected in a gasometer and the temperature and volume were recorded. Calculations of the residual volume were made by the procedure of Cournard (8), except that the nitrogen concentration of alveolar samples at the end of 7 min. of oxygen breathing was not determined, but an average correction of 1.2% was applied.

The values of residual volume determined during complete submersion were somewhat lower than those obtained under ordinary room conditions. For young subjects submersed in a seated position the mean value was 1.45 L., as compared with a value of 1.58 L. determined for subjects sitting in a room. The mean difference between the two sets of values approached but did not reach the 5% level of significance (6).

All residual volumes were calculated for conditions of temperature (37 C.) and approximate vapor saturation existing within the lungs.

RESULTS

Determinations of the residual volume were made in 28 young men (mean age 23 years) and 31 older men (mean age 52 years) under usual conditions (in air). The subjects were clinically free of gross bronchopulmonary symptoms, as evidenced by their medical history and physical and X-ray examinations. Some of the general physical characteristics of the subjects in the two groups are listed in table 1. Both groups of individuals are somewhat heavier on the average than men of the same height (3). The values of residual volume varied from 0.97 to 2.45 L. in the younger group, and from 1.52 to 3.31 L. in the older group. On the average the residual volume of the older men was 0.6 L. larger than in the younger subjects. This mean

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TABLE 1. GENERAL CHARACTERISTICS, RESIDUAL VOLUME (RV) AND VITAL CAPACITY (VC) DETERMINED UNDER ORDINARY ROOM CONDITIONS, IN YOUNGER AND OLDER MEN. TOTAL LUNG CAPACITY (TLC) = RV + VC. S.D.'s = STANDARD DEVIATIONS OF THE DISTRIBUTIONS.

	Younger Men (N = 28)		Older Men (N = 31)	
Characteristic	Mean	S.D.	Mean	S.D.
Age, years	23.0	2.3	52.0	3.3
Height, cm.	178.6	6.9	174.7	5.7
Weight, Kg.	75.5	11.7	79.7	13.1
Relative weight, %*	106.0	15.2	105.3	15.1
Residual volume, L.	1.57	0.42	2.17	0.52
Vital capacity, L.	5.00†	0.62	3.95	0.82
100 RV/TLC	24.4†	5.8	35.6	7.4

* Actual body weight, nude, as percentage of the standard reference weight for age, sex, and height (based on the 1912 standards, without correction for shoes or clothing; 1).
† N = 19.

TABLE 2. RESIDUAL VOLUME, DETERMINED IN AIR, IN A SUBSAMPLE OF YOUNGER AND OLDER MEN (MEAN AGES 23.2 AND 51.9 YEARS), MATCHED WITH REFERENCE TO THE AVERAGE HEIGHT AND WEIGHT.

	Younger Men (N = 22)		Older Men (N = 22)	
Characteristic	Mean	S.D.	Mean	S.D.
Height, cm.	176.8	5.8	176.0	6.3
Weight, Kg.	76.5	12.3	77.2	14.5
Residual volume, L.	1.49	0.36	2.16	0.48

TABLE 3. RESIDUAL VOLUME DETERMINED AT THE TIME OF SUBMERSION, IN NORMAL YOUNGER AND OLDER MEN. S.D. = STANDARD DEVIATION OF THE DISTRIBUTIONS.

	Younger Men (N = 33)		Older Men (N = 156)	
Characteristic	Mean	S.D.	Mean	S.D.
Age, years	25.2	2.0	52.2	2.7
Height, cm.	177.1	6.6	175.4	6.0
Weight, Kg.	75.0	15.0	75.2	10.6
Relative weight, %	106.2	14.6	98.8	13.2
Residual volume, L.	1.53	0.52	1.97	0.44

difference is statistically highly significant, with $F = 22.38$, compared with the reference value of $F_{0.01} = 7.10$.

As seen from the table the mean vital capacity was found to be 1 L. smaller in the older group than in the younger men. As a result of the difference in residual volume and vital capacity, the mean value of the residual volume, expressed as the percentage of the total lung capacity (TLC = residual volume + vital capacity), is markedly greater in the older men (35.6, range 26.1 to 57.9) than in the younger men (24.4, range 17.9 to 35.6).

As indicated in table 1, the two groups differed somewhat in gross body size, the older men being shorter and heavier. This might complicate the interpretation of the obtained differences in residual volume and vital capacity. Consequently an attempt was made to match the two groups with reference to stature and body weight and calculate the residual volume for the older and younger men under these conditions. The data for the subsample are summarized in table 2.

The difference in residual volume was in the same direction and of similar, somewhat greater magnitude (0.67 L.) than in the total samples. The statistical test indicates a highly significant difference, with an $F = 27.47$ as compared with $F_{0.01} = 7.27$.

Another set of measurements was obtained on men similar in age (33 younger men, 156 older men) and occupation to the first two samples but with residual volumes determined at the time of maximal expiration during complete submersion under water.

The older men had the same average absolute weight but were somewhat shorter than the younger men (table 3). This would make the appraisal of age difference in residual volume more conservative, if anything. The mean residual volume was again found to be larger in the older-age group, with a difference of 0.44 L. As in preceding comparisons, the difference is statistically highly significant ($F = 26.2$, compared to the reference value of $F_{0.001} = 11.0$) but absolute difference is somewhat smaller than observed in the other study when residual volumes were determined under ordinary room conditions.

The material on residual volume of middle-aged men is large enough to be examined with reference to the relationship, if any, with underweight-overweight. The results were tabulated accordingly (table 4) but no consistent trend is apparent. Except for the category of overweight individuals (relative weights of 115% and up), the height in different weight categories is almost identical and does not complicate the picture.

Data on vital capacity were available for 148 of these older men. The mean residual volume was 1.99 L., vital capacity 4.26 L., yielding a total lung capacity of 6.25 L. and relative residual volume of 31.8%, with 5.0% as the standard deviation of the distribution. As regards the 5 groups of relative weight, arranged from light to heavy, there was no indication of a trend in relative residual volume with underweight-overweight, except for some elevation in the thin individuals.

TABLE 4. PULMONARY VOLUMES IN RELATION TO UNDERWEIGHT—OVERWEIGHT IN MIDDLE-AGED MEN. M = MEAN, SD = STANDARD DEVIATION OF THE DISTRIBUTIONS.

Relative Body Weight, %		Below 85.0	85.0–94.9	95.0–104.9	105.0–114.9	115.0 and up
N		24	38	46	30	18
Age, years	M	51.9	52.3	51.9	53.2	51.2
Height, cm.	M	176.4	175.9	175.1	176.4	172.4
Weight, Kg.	M	60.8	69.5	76.2	84.4	88.7
Relative weight, %	M	78.7	90.5	100.4	109.4	121.3
Residual volume, L.	M	2.24	1.98	1.88	1.98	1.82
	SD	0.41	0.41	0.46	0.40	0.43
Vital capacity, L.	M	4.21	4.21*	4.34†	4.38‡	3.99§
	SD	0.79	0.55	0.64	0.69	0.48
100 RV/TLC‖	M	34.9	32.1	30.2	31.2	31.5
	SD	5.9	5.0	4.2	4.5	4.5

* N = 35
† N = 44
‡ N = 29
§ N = 16
‖ Based on subjects for whom both RV and VC were available.

TABLE 5. GENERAL CHARACTERISTICS OF THE SAMPLE OF 51 WOMEN AND THEIR PULMONARY VOLUMES. TOTAL LUNG CAPACITY (TLC) = RESIDUAL VOLUME (RV) + VITAL CAPACITY (VC). M = MEANS, SD = STANDARD DEVIATION OF THE DISTRIBUTIONS.

Age Group		18-29	30-39	40-49	50-63	Total
N		19	8	11	13	51
Age, years	M	24.1	35.2	44.9	56.1	38.5
	SD	2.9	2.6	2.1	4.3	13.4
Height cm.	M	163.6	166.4	161.5	160.5	162.8
	SD	6.6	6.1	6.5	6.3	6.5
Weight, Kg.	M	55.4	64.1	57.4	62.3	59.0
	SD	6.4	9.9	6.5	9.3	8.3
Relative weight, %	M	95.3	100.3	89.7	96.1	95.1
	SD	9.6	12.4	8.0	13.0	10.9
Residual volume, L.	M	1.26	1.42	1.71	1.82	1.53
	SD	0.31	0.19	0.35	0.41	0.40
Vital capacity, L.	M	3.28	3.49	3.08	2.63	3.10
	SD	0.45	0.42	0.54	0.36	0.53
100 RV/TLC	M	27.7	29.0	35.8	40.8	33.0
	SD	5.1	3.5	4.5	5.9	7.4

Data on both residual volume (measured during underwater weighing) and vital capacity (measured in a seated position under ordinary room conditions) are available for 51 normal adult women, varying in age from 18 to 63 years.

The data are summarized in table 5. The 4 age groups exhibit the expected tendency toward a decrease of height and increase in weight with advancing age. The small size of the subsamples accounts for the fact that the group means of the anthropometric characteristics exhibit some irregularities in the age trends. Also vital capacity is somewhat larger in the fourth decade (30-39 years) than in the third decade. Residual volume, on the other hand, shows a continuous increase with age.

Of principal interest in this context is the proportion between the residual volume and total lung capacity. For this purpose the differences in body length and weight are less important than when absolute pulmonary volumes are considered.

Means of relative residual volume for the 4 age groups of women, together with a line fitted by the least-square method, are given in figure 1. The equation for predicting relative residual air (Y) from age (X, in years) is $\hat{Y} = 17.17 + 0.41\ X$. It is clear that extrapolations should not be made much below 20 or above 60 years of age.

Statistical analysis indicated that there was no significant departure from linearity ($F = 1.11$; for 3 and 46 degrees of freedom the refer-

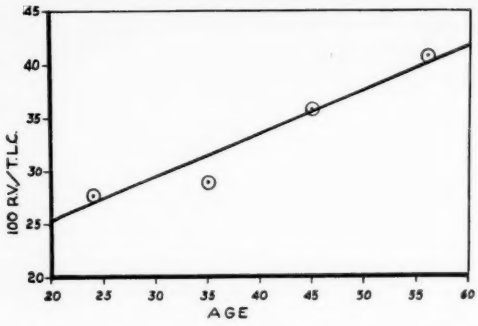

Fig. 1. Age trend in relative residual volume (100 RV/TLC) in women (N = 51). The circles indicate means for the 4 age groups. The line representing the least-square fit is based on individual observations.

ence value of $F_{0.05} = 2.81$) but a highly significant departure of the slope from the horizontal line ($F = 61.81$; for 1 and 49 degrees of freedom, $F_{0.01} = 7.18$). The degree of associabetween age and relative residual volume is characterized by an r of 0.747. This is an unusually high correlation for anatomical or physiological functions considered in relation to age in a clinically normal population.

DISCUSSION

A general tendency for vital capacity to decrease with age is well established. Rohrwasser (17) reported an average of 4.7 L. vital capacity for men aged 21-25, 4.2 at ages 26-35, 3.9 at ages 36-50, 3.6 at 51-60, and 3.2 at 61-72 years. Women showed a somewhat similar trend, with 3.5 L. as the average for ages 21 to 30 years and 2.9 L. for 36 to 45 years. Our values of 5.0 L. for men averaging 23 years and 3.9 L. for the older men (average age 52 years) fit closely the trend charted by Rohrwasser. In our sample of women the values decreased from 3.5 to 2.6 L.

In contrast to vital capacity, readily determined, more limited information is available on age trends of the residual volume in samples of clinically normal individuals covering an appreciable segment of the adult age range (2, 10, 12). The largest group of men (N = 135), evenly distributed over the age range from 24 to 87 years, was studied in regard to pulmonary function by Norris and associates (15). In the age range encompassing the ages of our subjects, the residual volume increased from 1.33 L. in the third decade, through 1.51 and 1.71 in the fourth and fifth decade, to 2.31 L. for the age group 50-59. Expressed as percentages of total lung capacity, the mean values correspond to 22.9, 26.7, 33.0, and 41.2%. In the present study the residual volume represented on the average 24% of the total lung capacity in the younger men. In the older men the value increased to 36%. For women, the percentages were 28 and 41, respectively.

The increase in one compartment of the total lung capacity (the residual volume), accompanied by a decrease in vital capacity indicates that the changes taking place in the normal process of aging, in the absence of specific pathology, must be taken into account in evaluating the clinical impairment of pulmonary function. Motley and associates (14) considered only the values over 35% as indicating a clinically significant degree of emphysema. Whitfield and associates (19) had expressed doubts as to whether even a Residual Volume/Total Lung Capacity ratio of over 40% can be accepted in clinical practice as a positive proof of the presence of pathological processes in the lungs. The present study, with the mean for older men (mean age 56 years) 40.8%, documents further the necessity for using age-corrected norms. This does not contradict the widely held opinion that emphysema as disease is in some ways a gross exaggeration of what happens to the lungs with advancing years (3).

Whitfield and associates (19) interpret the decrease in vital capacity and the increase in residual volume with age as the result of a diminished mobility of the thoracic cage and decreased elasticity of the lung parenchyma. Bates and Christie (3) ascribe the reduction in vital capacity not to a decrease in the distensibility of the lung itself but to the fixation of the thoracic cage, arising from a variety of anatomical changes, such as the decreased elasticity of the costal cartilages. The increase in functional residual capacity is attributed to diminished elastic recoil of the lung.

Pierce and Ebert (16) confirmed in white men over 65 years of age the familiar increase in residual volume and decrease in vital capacity as compared to healthy young individuals. The average value of residual volume, expressed as percentage of the total lung capacity, was 45.1% Of specific interest are their data indicating a marked change in the over-all elastic properties of the lungs. At a given level of lung inflation, the static intrathoracic pressure was less negative in the aged than in the

young normal subjects, indicating reduced elastic recoil of the lungs and thorax. Also there was a qualitative change in the pressure-volume diagram (relatively rectilinear in the young, curvilinear in the aged) seen in patients with pulmonary emphysema. Available data do not provide conclusive evidence regarding the mechanism involved in the observed alteration of the elastic properties of the lungs (change in the elasticity of existing fibers, reduction in the number of elastic fibers, or a combination of factors).

Whitfield and associates (19) examined the age trends in pulmonary volumes in terms of coefficients of correlation. Their samples consisted of 58 males and 31 females and covered the age range from 10 to 70 years. Vital capacity correlated negatively with age (r's of -0.423 and -0.366), residual air positively ($r = +0.346$ and $+0.239$), while in the total lung capacity there was a negligible trend toward lower values at higher ages ($r = -0.146$ and -0.117). The correlation with age for the Residual Volume/Total Lung Capacity ratios was somewhat higher ($r = +0.464$ and 0.441) than for either of the two items on which this ratio is based. In our series of women between 18 and 63 years the r was still higher ($r = +0.747$). It seems that the relative residual volume may be useful in a battery of criteria of the physiological age of an individual. It remains for future research to decide whether the lung volumes provide a better characterization of the normal aging of the respiratory system than the more dynamic measures, such as the peak expiratory flow rates, studied by Higgins (11).

SUMMARY

Measurements of residual volume and vital capacity were made in college students (mean age 23 years), in middle-aged business and professional men (mean age 52 years), and in women ranging in age from 18 to 63 years.

In the majority of cases the residual volume was obtained in connection with determinations of body volume by the method of underwater weighing. In addition, in two groups of men the residual volume determinations were made in air and, in a small group, both in air and under water, one year apart. Vital capacities were determined in the usual manner.

In all age comparisons there was a tendency for the residual volume to increase with age and vital capacity to decrease with age.

The average values of residual volume, expressed as percentage of total lung capacity, were 24.4% for 19 young men and 27.7% for 19 young women, 31.8% for 148 older men (range 47 to 57 years), and 40.8% for 13 older women (range 50-63 years).

The age trend of relative residual volume was linear and statistically highly significant in 51 women aged 18 to 63 years.

The implications of the age trends for the clinical evaluation of emphysema were briefly noted.

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BOOK REVIEWS

AGEING OF HUMAN ARTERIAL TISSUE. BIOCHEMICAL STUDIES ON THE ACID MUCOPOLYSACCHARIDES, by Martin O. Dyrbye, Ejnar Munksgaard, Ltd., Copenhagen, 1959, 54 pages, paper bound, Dan. kr. 15.00.

Many investigators in the field of arteriosclerosis focus their interest upon the problem of lipid metabolism. There has been a tendency to neglect the parietal factor in attempts to explain the pathogenesis of atheromatous deposits. Those who did scrutinize the early changes of the arterial wall have usually resorted to histological examinations.

Dr. Dyrbye has investigated the changes of the acid mucopolysaccharides in the arterial tissue by biochemical methods that he helped develop. This investigation was made partly at the Division of Gerontology, Washington University School of Medicine, St. Louis, and partly at the Connective Tissue Research Laboratory, University Institute of Medical Anatomy, Copenhagen.

After a short introduction, the chemistry of acid mucopolysaccharides is reviewed. The research work of the author, conducted on human aortas, and pulmonary and cerebral arteries, concerns the concentration of hexosamine and acid-hydrolyzable sulphate, the isolation and analysis of the acid mucopolysaccharides, and the *in vitro* uptake of S^{35} labelled inorganic sulfate in acid mucopolysaccharides. Attention is given especially to changes related to age and arteriosclerosis. Of particular importance is the observation by Dr. Dyrbye that the uptake of S^{35} labelled sulfate by human aortic tissue *in vitro* decreased definitely with age and increasing arteriosclerosis.

The author concludes that the acid mucopolysaccharides in arterial tissue are perhaps of essential importance for changes with age in the arterial tissues and especially for the development of arteriosclerosis.

This basic contribution to a crucial, albeit elusive, problem contains much experimental material and will stimulate further research.

R. SCHAUS, M.D.
Luxembourg

DUKE UNIVERSITY COUNCIL ON GERONTOLOGY. PROCEEDINGS OF SEMINARS, 1958-59, edited by F. C. Jeffers, Durham, N. C., 1959, 88 pages, paper bound, $1.00.

Among the 6 seminar reports included in this volume, the one by Margaret B. Luszki on "The Challenge of the Interdisciplinary Team Approach in Research" is of special interest. The author outlines many of the problems encountered in interdisciplinary research and offers specific suggestions for meeting them. Her descriptions of how psychiatrists, psychologists, anthropologists, and sociologists see themselves and how they are seen by others highlight the problems of communication among members of an interdisciplinary research team.

Dr. W. M. Johnson describes in some detail the formation, activities, and general philosophy of the Committee on Aging of the American Medical Association. Dr. J. W. McConnell considers the impact of investment of pension funds on the economy. He points out the desirability of coordinated research programs on socio-economic problems in order to secure valid answers for the country as a whole. Arthur Larson contends that it is the duty of all groups, including physicians with better than average incomes, to participate in the social security system. He also presents cogent arguments for a better coordination between different aspects of social insurance programs in the United States so that the middle-aged worker will not be chained to his job. Mr. Larson also argues for providing hospital and medical insurance for social security beneficiaries where the need for these services exists.

Dr. J. A. Pons defends the thesis that dizziness in old people is more prevalent in those who have always had difficulty in adjusting to changes in life situations than in more adaptable individuals. Dr. Brooke Roberts describes some results of surgery of degenerative arterial disease.

N. W. SHOCK
Baltimore City Hospitals

THE OLDER PATIENT, by twenty-one authors, edited by Wingate M. Johnson, M.D., Paul B. Hoeber, Inc., New York, 1960, 564 pages with index, $14.50.

This book was designed "not to serve as a textbook on the practice of medicine but to complement such works," to be of assistance to those who care for older patients. It is largely the product of the faculty of the Bowman Gray School of Medicine. The 26 short chapters range from the how and why of the physical examination over the broad area of medical specialties, ending with comments to adjustment to old age.

This reviewer is at a loss to whom to recommend the book. It is clearly not for the gerontologist—or the geriatrician, if there is a difference. The authors rarely refer to work done in this field in the last 10 years, and many of their statements suggest that they are not sufficiently acquainted with it. It lacks the depth and the challenge of books now available, such as those by Lansing and by Stieglitz. Nor is it for the internist who keeps up with his journals and who can refer to textbooks for more precise information on points that concern him. If it is directed to the general practitioner, the presentation of the material is such as to show him conceived of as one ignorant of much modern medicine and probably satisfied with simple directions. Since the "older patient" seems to be thought of as well on the down-hill road of deterioration, it is not attractive to the lay person.

There is a great need for information as to if, how, and why the manifestations of disease in older people vary from those to be expected in the young or middle-aged. There is also a great need to learn what individuals are, in sickness and in health, in the doctor's office and outside of it. These are tremendous tasks and they cannot be performed by physicians alone. Dr. Johnson's warm-hearted and long interest in this area should serve to stimulate us all.

ROBERT T. MONROE
Boston, Mass.

BOOKS RECEIVED

Acute Pericarditis, by David H. Spodick, Grune & Stratton, Inc., New York, 1959, 175 pages, $6.50.

Ageing of Human Arterial Tissue. Biochemical Studies of the Acid Mucopolysaccharides, by Martin O. Dyrbye, Ejnar Munksgaard, Ltd., Copenhagen, 1959, 54 pages, paper bound, Dan. kr. 15.00 (reviewed in this issue, page 161).

Carcinogenesis, Mechanisms of Action, edited by G. E. W. Wolstenholme and Maeve O'Connor, Ciba Foundation Symposium, Little, Brown & Co., Boston, 1959, 336 pages, $9.50.

Conquest of Age. The Extraordinary Story of Dr. Paul Niehans, by Gilles Lambert, Rinehart & Co., Inc., New York, 1959, 220 pages, $3.95.

Diagnosis and Treatment of Tumors of the Chest, edited by David M. Spain, Grune & Stratton, New York, 1960, 371 pages, $14.75.

Duke University Council on Gerontology. Proceedings of Seminars, 1958-1959, edited by Frances C. Jeffers, Regional Center for the Study of Aging, Duke University, Durham, North Carolina, 1959, 88 pages, paper bound, $1.00 (reviewed in this issue, page 161).

Handbook of Aging and the Individual. Psychological and Biological Aspects, edited by James E. Birren, University of Chicago Press, 1959, 939 pages, $12.50.

La Longévité chez l'Araignée, by A. Bouillon and G. Krumbach, University of Leopoldville, Belgian Congo, 1958, 20 pages, paper bound.

Patterns of Incidence of Certain Diseases Throughout the World. Opportunities for Research Through Epidemiology. Prepared for the Committee on Government Operations United States Senate and its Subcommittee on Reorganization and International Organizations, U. S. Government Printing Office, Washington, D. C., November 9, 1959, 54 pages, paper bound, 20 cents.

Regulation of Cell Metabolism, edited by G. E. W. Wolstenholme and Cecilia M. O'Connor, Ciba Foundation Symposium, Little, Brown & Co., Boston, 387 pages, 1959, $9.50.

The Arterial Wall. Aging, Structure, and Chemistry, edited by Albert I. Lansing, The Williams & Wilkins Company, Baltimore, 1959, 259 pages, $7.50.

Tragödie des Genius. Genialität, Altern, Tod, by Dimu Kotsovsky, Pragerstr. 8/III, München 45, Germany, 1959, 383 pages.

ERRATUM

Dr. Sadamu Watanabe has requested that we publish a notice to the effect that the sentence beginning on line 31, the second column of page 301, Volume 14, (1959) of the Journal of Gerontology should read: "This hypocholesterolemia in the Japanese might be related to the low incidence of heart disease, especially in the rural districts."

JOURNAL OF GERONTOLOGY

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Section B

Psychological and Social Sciences, Social Welfare

Edited by

Robert J. Havighurst, Ph.D.
Bernice L. Neugarten, Ph.D.

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VOLUME 15, SECTION B APRIL, 1960 NUMBER 2

THE EFFECT OF RETIREMENT ON PERSONAL ADJUSTMENT: A PANEL ANALYSIS

WAYNE E. THOMPSON, Ph.D., GORDON F. STREIB, Ph.D., AND JOHN KOSA, Ph.D.
(Department of Sociology and Anthropology, Cornell University, Ithaca, N. Y.)

Research findings which compare the retired and the gainfully employed typically show a higher incidence of maladjustment among retirees. (*Cf.*, among others, Havighurst & Albrecht, 1953; Kutner, Fanshel, Togo, & Langner, 1956.) Such findings seem to support the assumption that personal adjustment and morale depend upon having a clear-cut position in a social structure and the corollary hypothesis that loss of status and work role at retirement leads to maladjustment and demoralization. It may be, however, that the chances of retirees finding a satisfactory "retirement role" has been underestimated—both in terms of the personal flexibility of the older person and the extent to which the institutional milieu provides or permits the opportunity to do so.

At the same time, the significance to the individual of the social aspects of his job may have been overemphasized. Given the bureaucratic, impersonal relationships and the assembly-line monotony of the contemporary industrial setting, there is no reason to suppose that attractive informal relationships are distinguishing characteristics of the work situation. In fact, when one considers the situation of the typical industrial worker, it hardly seems surprising that large numbers agree that "a job is just a way to make a living."

At the very least, then, it might be expected that maladjustment of retirees would not be the result of retirement *per se*, but rather would vary with attitudes toward work and retirement and with the circumstances of retirement. The present study is focused on the following questions: (1) Are retirees any more likely than the gainfully employed to become maladjusted through time? (2) If so, to what extent and under which circumstances does retirement have its deleterious effects?

THE SAMPLE

The analysis is based upon panel data of the Cornell Study of Occupational Retirement. When the respondents were first contacted in 1952-53, all were gainfully employed. At the second contact in 1954, somewhat more than a quarter had retired. The first contact was made largely in person at the respondents' place of work; four subsequent contacts have been by mail. The present analysis examines changes which occurred during the year and a half between the first and second contacts. As a part of a larger program of analysis, however, the present sample is limited to those who were still actively participating in the study at the time of a third contact in 1956. The sample is also limited to males of like age, all having been born either in 1887, 1888, or 1889.

The respondents do not constitute a representative sample of America's older population. Participation of both industrial organizations and individuals was necessarily voluntary, accounting in part for a comparatively high incidence of relatively larger, more affluent and more progressive organizations and of relatively more prosperous and better educated individuals. At the same time, the respondents are or were employed in most of the major types of industry; they are from all walks of life; and they are from all parts of the country.[1]

THE TECHNIQUE OF ANALYSIS

As indicated above, the analysis makes use of the panel technique. That is, the same people have been contacted at different times; and the investigators are therefore in a position to go

[1] For a more complete description of the Cornell Study of Occupational Retirement, see Streib, Thompson, & Suchman, 1958, pp. 3-17. This study was originally supported by the Lilly Endowment, Inc., of Indianapolis, Indiana, and more recently has been supported by the National Institute of Mental Health, United States Public Health Service (Grant M-1196).

beyond a simple comparison of the retired and gainfully employed in terms of incidence of poor adjustment. Instead, the multiple contacts with the participants provide the opportunity to compare changes which occur between points in time. Putting it another way, the study design permits the following question: given a certain adjustment score in 1952, at which time all were gainfully employed, are there differential changes among those who subsequently retired as compared with those who continued on the job?

Indices of Personal Adjustment

To measure changes in personal adjustment three indices have been devised through the use of the Guttman scaling technique (Guttman, 1944; Stouffer *et al.*, 1950). These have been entitled "Satisfaction with Life," "Dejection," and "Hopelessness" and are composed of the following items:

Satisfaction with Life. "All in all, how much happiness would you say you find in life today?" [Negative response: "Almost none"; or "Some, but not very much."]

"In general, how would you say you feel most of the time, in good spirits or in low spirits?" [Negative response: "I am usually in low spirits"; or "Sometimes in good spirits, sometimes in low spirits."]

"On the whole, how satisfied would you say you are with your way of life today?" [Negative response: "Fairly satisfied"; "Not very satisfied"; or "Not satisfied at all."]

Reproducibility = .96, Error Ratio = .55

Dejection. "How often do you get the feeling that your life today is not very useful?" [Negative response: "Often"; or "Sometimes."]

"How often do you find yourself feeling 'blue'?" [Negative response: "Often"; or "Sometimes."]

"How often do you get upset by the things that happen in your day-to-day living?" [Negative response: "Often"; or "Sometimes."]

Reproducibility = .96, Error Ratio = .49

Hopelessness. Agree-Disagree: "These days I find myself giving up hope of trying to improve myself." [Negative response: "Yes"; or "Undecided."]

Agree-Disagree: "Almost everything these days is a racket." [Negative response: "Yes"; or "Undecided."]

"How much do you plan ahead the things that you will be doing next week or the week after?" [Negative response: "I make almost no plans"; or "I make few plans."]

Reproducibility = .95, Error Ratio = .51

In the analysis which follows, each of these indices will be used separately, but it is important to note that both in 1952 and in 1954 the three indices themselves relate in a typical Guttman scalar pattern. That is to say, there is an empirical ordering of responses to the three indices which suggests that a single dimension of adjustment is indexed by each. Put more concretely, the pattern of responses is such that those "without hope" are likely also to be "dejected" *and* "dissatisfied with life"; those who are "dejected" are likely also to be "dissatisfied with life" but may or may not be "without hope"; and, finally, those who are "dissatisfied with life" may or may not also be "dejected" and "without hope," but those who are *not* dissatisfied almost certainly will be *neither* dejected *nor* without hope. Thus the three indices are deemed to represent points on what might be called an adjustment continuum, ranging from "Satisfaction with Life," with about 50 per cent of the respondents dissatisfied, to "Hopelessness," the most extreme of the three, with only about 10 per cent of the respondents "lacking hope."

FINDINGS

Retirement and Personal Adjustment

Overall, it would appear that if retirement has an impact on adjustment, it is reflected most clearly by the least extreme index, "Satisfaction with Life" (Table 1).[2] Although the retirees consistently are more likely than the employed to decline in personal adjustment, the changes are negligible except on this index. In general, the view that retirement has negative effects does not seem to be supported by the evidence. In fact, Table 1 shows that the retirees are consistently the more likely to show gains in personal adjustment. Although the percentage differences are small, one is tempted, particularly in observing the index "Hopelessness," to advance the hypothesis that for some people retirement may be a matter of escaping from an intolerable work situation to a less demanding situation from which the future appears somewhat brighter. Implicit in this hypothesis is an emphasis on the individual's perception of work and retirement, suggesting again the possibility that the effects of retirement are conditioned by the attitude with which it is approached.

[2] The tables presented show changes as measured by the three indices separately. The changes which are reported may reflect a "one-step" change (e.g., became dissatisfied, but remained not dejected and hopeful), a "two-step" change (e.g., became dissatisfied and dejected, but remained hopeful), or a "three-step" change (e.g., became dissatisfied, dejected, and hopeless) on the over-all scale. In other words, the dependent variable to be examined here is any change in adjustment, without specification of the extent of change.

Orientation and Adjustment. The index of the pre-retirement attitude toward retirement used here includes the following items:

"Some people say that retirement is good for a person, some say it is bad. In general, what do you think?" [Negative response: "Mostly bad."]

"Do you mostly look forward to the time when you will stop working and retire or in general do you dislike the idea?" [Negative response: "Dislike the idea"; or "Undecided."]

"If it were up to you alone, would you continue working for your present company?" [Negative response: "I would continue working."]

Reproducibility 1952 = .96, Error Ratio 1952 = .32
Reproducibility 1954 = .95, Error Ratio 1954 = .48

This attitude is, of course, not the same thing as "voluntary" as opposed to "compulsory" retirement, since the latter refers to the administrative circumstances of retiring. However, locus of the decision to retire often has been cited as a factor in adjustment and may have an independent effect. Therefore, for the purposes of this analysis, it is included with the pre-retirement attitude toward retirement as an aspect of orientation to retirement. That is to say, company versus personal decision to retire and pre-retirement willingness or reluctance are cross-tabulated, yielding the following four categories:

Willing Voluntary Retirees — those whose pre-retirement attitudes were favorable and who made the decision to retire themselves;

Willing Administrative Retirees — those whose pre-retirement attitudes also were favorable, but who retired under company edict;

Reluctant Voluntary Retirees — those who held unfavorable attitudes but who nevertheless chose personally to retire, frequently for health reasons;

Reluctant Administrative Retirees — those whose attitudes were unfavorable but for whom company policy made retirement mandatory.

The relationship between orientation to retirement and personal adjustment is presented in Table 2. Examining first "Satisfaction with Life," it would appear that the willing retirees are no more likely to become dissatisfied than are those who remained gainfully employed; but that those who are reluctant to retire are very much more likely to become dissatisfied.

A similar picture is revealed by the findings on "Dejection." Here also, reluctance to retire is associated with a higher incidence of becoming dejected among the retirees, but those who were willing to retire do not differ from those who continue in gainful employment. Moreover, it is the willing retirees who are the most likely of all—including the gainfully employed—to cease being dejected between the two times of contact.

However, this relationship between pre-retirement attitude and adjustment does not appear on the most extreme measure, "Hopelessness." Here no differences are found between the willing and the reluctant retirees, nor, in fact, among any of the retirees when compared with the gainfully employed.

In all, it would appear that the negative effects of retirement have generally been overestimated. Changes in the direction of maladjustment occur only when the retirees hold an unfavorable pre-retirement attitude toward retirement and then only as indexed by the two less extreme indices of personal adjustment. Beyond this, the findings seem to indicate that company versus personal decision is of little or no consequence, a fact which underscores the need to keep analytically separate the individual's perspective and the administrative circumstances under which he retires.

TABLE 1. CHANGES IN PERSONAL ADJUSTMENT BETWEEN 1952 AND 1954 AMONG THOSE WHO CONTINUED IN GAINFUL EMPLOYMENT AND THOSE WHO RETIRED.

	Gainfully employed throughout (N=1082)	Retired between 1952 and 1954 (N=477)
"Satisfaction With Life":		
Percentage of those "satisfied" in 1952 who became "dissatisfied"	34% (550)	44% (238)
Percentage of those "dissatisfied" in 1952 who became "satisfied"	22% (532)	26% (239)
"Dejection":		
Percentage of those "not dejected" in 1952 who became "dejected"	14% (810)	19% (349)
Percentage of those "dejected" in 1952 who ceased being "dejected"	49% (272)	51% (128)
"Hopelessness":		
Percentage of those "hopeful" in 1952 who "lost hope"	10% (1003)	12% (416)
Percentage of those "without hope" in 1952 who became "hopeful"	62% (79)	77% (61)

NOTE.—The number within parentheses in this and subsequent tables is the percentage base. The percentages presented are the "changers." For example, the top left-hand cell of the table tells us that of 550 persons among the gainfully employed who were satisfied with their life in 1952, 34 per cent became dissatisfied between 1952 and 1954. Similarly, of 532 persons among the gainfully employed who were dissatisfied in 1952, 22 per cent became satisfied between 1952 and 1954. This same pattern of presentation is used throughout the paper.

The Retirement Experience as a Factor in Adjustment. To this point variations in personal adjustment have been related only to pre-retirement orientation. Clearly, retirement varies among retirees not only in preconception but also in experience. For example, it is commonplace knowledge that retirement leads to a reduction of economic means; yet not all retirees feel economically deprived. Similarly, not all retirees consider that they have too much free time in retirement. A further refinement of the analysis, therefore, tests the proposition that changes in personal adjustment will accompany retirement only if the retiree feels economically deprived, finds it difficult to keep occupied, or is in poor health.[3]

As shown in Table 3, each of these situational factors in itself is related to becoming dissatisfied with life both among the retirees and the gainfully employed; but Table 3 also shows that the relationship between pre-retirement reluctance and negative shifts in satisfaction persists even among those who are not deprived, who are in good health, and who do not have difficulty in keeping occupied.

In the case of "Dejection" (Table 4), the relationship between situational factors and changes in adjustment again appears; however, the relationship between reluctance and changes in adjustment is less clear. Only among those who are in poor health or who have a problem in keeping occupied do we find a marked difference between the reluctant retiree category and the other categories. In other words, at this level of adjustment, even reluctance to retire as a factor in adjustment seems to be conditioned by the circumstances of retirement as it is experienced.

[3] Research findings consistently show a higher incidence of poor health among retirees than among gainfully employed; however, previous findings from the Cornell study indicate that poor health is not the result of retirement. Rather, the incidence of illness among retirees is better explained by the fact that people in poor health tend to retire. (Cf. Thompson & Streib, 1958, pp. 18-34.)

TABLE 2. CHANGES IN PERSONAL ADJUSTMENT BETWEEN 1952 AND 1954 AMONG CATEGORIES OF RETIREES.

	Gainfully employed throughout	Retired between 1952 and 1954			
		Willing voluntary	Willing administrative	Reluctant voluntary	Reluctant administrative
"Satisfaction With Life":					
Percentage of those "satisfied" in 1952 who became "dissatisfied"	34% (550)	31% (75)	39% (74)	64% (22)	57% (67)
Percentage of those "dissatisfied" in 1952 who became "satisfied"	22% (532)	29% (65)	42% (84)	26% (23)	19% (67)
"Dejection":					
Percentage of those "not dejected" in 1952 who became "dejected"	14% (810)	13% (98)	10% (110)	27% (37)	20% (104)
Percentage of those "dejected" in 1952 who ceased being "dejected"	49% (272)	57% (42)	58% (48)	.....[a]	43% (30)
"Hopelessness":					
Percentage of those "hopeful" in 1952 who "lost hope"	10% (1003)	12% (121)	11% (136)	10% (42)	12% (113)
Percentage of those "without hope" in 1952 who became "hopeful"	62% (79)	.....[a]	73% (22)	.....[a]	67% (21)

NOTE.—Number within parentheses is the percentage base.
[a] Too few cases to be included in the analysis.

TABLE 3. CHANGES IN "SATISFACTION WITH LIFE" BETWEEN 1952 AND 1954, HOLDING CONSTANT 1954 "ECONOMIC DEPRIVATION," "SUBJECTIVE HEALTH," AND "DIFFICULTY KEEPING OCCUPIED."

Of those persons "satisfied with life" in 1952, the percentages who became "dissatisfied" in 1954 among:	Gainfully employed	Willing retirees	Reluctant retirees
Not "deprived," 1954	31% (500)	30% (125)	51% (57)
"Economically deprived," 1954	60% (50)	58% (24)	71% (31)
"Good health," 1954	24% (399)	27% (97)	54% (52)
"Poor health," 1954	60% (151)	50% (52)	64% (23)
No difficulty keeping occupied, 1954	31% (474)	30% (110)	45% (55)
Difficulty keeping occupied, 1954	53% (76)	49% (39)	79% (34)

NOTE.—Number within parentheses is the percentage base.

Finally, in the case of "Hopelessness" (Table 5), although some differences may be noted, it is not even clear that situational factors may be related to changes in the direction of maladjustment; and certainly there are no differences attributable to retirement *per se*.

DISCUSSION

In general, retirement appears to have a negative effect upon personal adjustment only insofar as it has an effect upon economic wherewithal (and attendant feelings of income adequacy or economic deprivation) and upon difficulty in keeping occupied. Also, as indexed by the least extreme of the indices used in this analysis, reluctance to retire evidently plays an independent part in changes in personal adjustment. However, there is no evidence that extreme maladjustment is a typical result of retirement even among those who are economically deprived, are in poor health, or are finding it difficult to keep occupied.

It seems clear that oversimplified, unqualified views of retirement are not adequate for a proper understanding of its effects. Rather, the negative effect of retirement often presumed to be indicated by cross-sectional research findings must be related to a more clearly specified conception of retirement, one which at the very least varies with pre-retirement attitudes toward retirement and with the specific retirement experience.

The findings presented here cannot be claimed to refute the propositions that personal adjustment depends upon a clear-cut position in a social structure and that adjustment varies with changes in status and role. The findings do suggest, however, that for many people the work role is not as central to the personality as many writers would contend.

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TABLE 4. CHANGES IN "DEJECTION" BETWEEN 1952 AND 1954, HOLDING CONSTANT 1954 "ECONOMIC DEPRIVATION," "SUBJECTIVE HEALTH," AND "DIFFICULTY KEEPING OCCUPIED."

Of those persons not "dejected" in 1952, the percentages who became "dejected" in 1954 among:	Gainfully employed	Willing retirees	Reluctant retirees
Not "deprived," 1954	10% (729)	7% (164)	14% (87)
"Economically deprived," 1954	32% (81)	27% (44)	36% (53)
"Good health," 1954	10% (555)	8% (131)	14% (79)
"Poor health," 1954	17% (255)	17% (77)	33% (61)
No difficulty keeping occupied, 1954	11% (690)	7% (153)	10% (87)
Difficulty keeping occupied, 1954	22% (120)	25% (55)	41% (54)

NOTE.—Number within parentheses is the percentage base.

TABLE 5. CHANGES IN "HOPELESSNESS" BETWEEN 1952 AND 1954, HOLDING CONSTANT 1954 "ECONOMIC DEPRIVATION," "SUBJECTIVE HEALTH," AND "DIFFICULTY IN KEEPING OCCUPIED."

Of those persons "hopeful" in 1952, the percentages who "lost hope" in 1954 among:	Gainfully employed	Willing retirees	Reluctant retirees
Not "deprived," 1954	7% (911)	12% (213)	10% (107)
"Economically deprived," 1954	13% (125)	11% (63)	9% (80)
"Good health," 1954	6% (679)	6% (162)	5% (117)
"Poor health," 1954	12% (357)	21% (114)	17% (70)
No difficulty keeping occupied, 1954	6% (854)	9% (192)	8% (105)
Difficulty keeping occupied, 1954	16% (182)	18% (84)	12% (82)

NOTE.—Number within parentheses is the percentage base.

FAMILY STRUCTURE AND SOCIAL ISOLATION OF OLDER PERSONS*

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The past three-quarters of a century or more in the United States has been portrayed as a period of rapid social change in which there have been significant modifications in family social organization and structure. Changes in the American family are thought to have had especially important implications for older persons.

Among the modifications in family relations which have been reported in the literature are: increased cultural diversity between older and younger generations, increased mobility of children, and reduced parent-child interdependence. (Burgess, 1957; Drake, 1958; Parsons, 1949a; Parsons, 1949b). Such changes have been seen as important factors in the emergence of the nuclear family group as predominant, and in the lessening of the degree of family solidarity. These changes in the family are presumed, furthermore, to be occurring at a greater rate, or to have proceeded further, in urban than in rural areas.

It has been suggested that among the consequences of these modifications in family social organization and structure have been the isolation of older persons from their children and the development of feelings of neglect and loneliness (Parsons, 1949 b, p. 230). Other authors, however, have suggested that, as a result of such changes, the older person is now drawn closer to his children by bonds of affection. (Burgess, 1957, p. 171).

From this apparent disagreement in interpretation were derived the problems for investigation in this exploratory study: To what extent are older persons in an urban area physically and socially isolated from their children? Does isolation, where it exists, lead to feelings of neglect or loneliness? Or do such feelings tend to vary independently of isolation and to depend, rather, upon the relationship between older persons' expectations of their children and their children's actual behavior?

METHOD

As part of a multi-disciplinary research project on aging, 260 elderly persons, age 60 and over, were intensively interviewed about social factors in their life situations and about their attitudes toward a variety of life experiences. Two social workers conducted the interviews, using a 30-page schedule which incorporated items from the Burgess, Cavan, and Havighurst "Your Activities and Attitudes" inventory (Cavan, Burgess, Havighurst, & Goldhamer, 1949) and the Albrecht "Role Activities" scales (Havighurst & Albrecht, 1953).

The subjects were volunteers recruited from Durham and other nearby North Carolina communities. No elderly persons living in institutions were interviewed in this study. Initially the recruitment process consisted of requesting volunteers by means of radio and television appeals and at Golden Age Club meetings, and of writing letters to retired university professors and school teachers. Through these and other contacts, principally former subjects, the study sample was built up over a four-year period. By these procedures, bed-ridden, immobile, or socially isolated persons were omitted from the sample. Thus, the methods used to obtain the subjects do not provide a clear definition of a population to which generalizations might be made; therefore, any application of our findings to old people in general should be avoided.

For statistical analysis, 161 residents of the city of Durham, who had living children, were selected from the total study sample. These subjects had the following characteristics: 53 per cent were male, and 47 per cent female; 59 per cent were white and 41 per cent Negro; about half were under and half over 70 years of age; 62 per cent were married, 32 per cent widowed, and 6 per cent separated or divorced. They varied widely in social class, a point that will be elaborated below.

FINDINGS

A majority of the elderly subjects were found to be maintaining a nuclear family pattern, as defined by living arrangements, at the time of

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the interviews. Our data, for example, showed that 60 per cent of the older persons in the sample did not live with their children or other relatives. The predominance of such a separate dwelling pattern, also generally reported for older persons in present-day American society as a whole, usually is attributed, in part, to grown children's high degree of geographical mobility. Data in this study indicated that the children of our subjects apparently did not differ from the general pattern in this regard: A pattern of geographical mobility of their adult children was found to obtain for a majority of elderly parents. The extent of adult children's geographical mobility was measured by the percentage of an elderly subject's living children who resided in Durham at the time of the interview. Nearly two-thirds (64 per cent) of the 157 subjects for whom there was complete data reported that one-half or more of their children did not live in Durham. Of these, 50 per cent had none of their children living in Durham, and the other 50 per cent had some, but no more than half, of them residing there. On the other hand, only 36 per cent of the subjects stated that one-half or more of their children lived in Durham; of these, however, 58 per cent had all of their children living there. In spite of this pattern of children's mobility, it is important to note that in 78 per cent of the cases elderly parents and at least some of their children lived in the same community.

The distribution of subjects on an Albrecht "Role Activities" scale, "Role as Parent," served as an indicator of the nature of the subjects' relationships with their children. This scale, which was used as a rough measure of parent-child dependency, is constructed as follows:

0 Never visited by children. No interest in them; rejects them.

1 No interest in children; too old or too ill to care.

2 Knows little about children, where they are, etc. Seldom hears from them.

3 Sees children occasionally, or depends upon them.

4 Shares children's home; somewhat burdensome.

5 Shares home of children; a help rather than a burden.

6 Slight dependence on part of children; some responsibility for them.

7 Responsible for children full or part time (children dependent).

8 Independent; occasional advice to children or needs their advice. Child may live with parent.

9 Mutual independence, but close social and affectional relationship (Havighurst & Albrecht, 1953, p. 376).

In a parent-child relationship, for example, "some form of dependency" was defined as including: (a) the older person dependent on his child(ren); (b) child(ren) dependent on their parent(s); and (c) mutual dependence of parent(s) and child(ren). These constitute items 3-7 on the scale.

In 41 per cent of the 156 cases for whom we had adequate data there existed some form of dependency in the relationships of children and aged parents. An additional 17 per cent of the subjects and their children, though mutually independent, were reported to have close social and affectional relationships (Item 9 on the scale). Thus, 58 per cent of the subjects had relationships with their children characterized either by some type of dependency, by affectional ties, or both.

These data suggest that, in spite of the existence of separate dwelling and geographical mobility patterns, our older subjects lived in close proximity to at least some of their children. In addition, the relationships of most of these older persons with their offspring was characterized by some form of dependency, by close social and affectional relationships, or by both.

Furthermore, a majority of the subjects did not appear to live in social isolation from their children. Degree of social isolation, defined in terms of frequency of contact with children, was dichotomized into "sees children less than weekly" and "sees children weekly or oftener." Sixty-eight per cent of the 145 elderly parents from whom complete data had been collected tended to maintain relatively frequent contacts (*i.e.*, weekly or oftener) with their children. In addition, it would seem that this high frequency of parent-child interaction was closely related to a low prevalence of reported feelings of neglect.

In the course of the interviews our subjects were asked: "Do you think your family or close relatives neglect you?" Eighty-one per cent of all subjects responded "Not at all" to this question, while 19 per cent said they thought they had been neglected "completely" or "a little." This variable, which has been called "expressed feelings of neglect," represents a statement of a person's perception of the state of the relationship between members of his family and himself. Implicit in this notion is an underlying set of expectations which pertain to the mainte-

nance of the relationships in some form so that: 1) if the members of the subject's family conform to his expectations he will report no feelings of neglect, or 2) if they deviate from his expectations he will report feelings of neglect. An attempt has been made in this study to determine the nature of elderly parents' expectations, conformity to and deviation from which would explain the observed variation in expressed feelings of neglect.

A part of the variation in expressed feelings of neglect may be explained by the frequency of contact between parents and their children. Table 1 reveals that subjects who saw their children weekly or more were significantly less likely to express feelings of neglect than those who saw them less than weekly. Furthermore, as shown in Table 2, subjects who did not live with their children were no more likely than those who lived with them (and therefore were assured of frequent contact) to express feelings of neglect. At the same time, however, it should be noted (see Table 1) that whereas only 13 per cent of the subjects who saw their children weekly or more expressed feelings of neglect, as many as 70 per cent who saw their children less than weekly reported no feelings of neglect. This relationship suggests that, while infrequent parent-child interaction appeared to constitute a sufficient condition for reports of neglect, infrequent interaction was not a necessary condition.

TABLE 1. RELATIONSHIP BETWEEN EXPRESSED FEELINGS OF NEGLECT AND FREQUENCY OF CONTACT WITH CHILDREN.

Expressed Feelings of Neglect by Family	Frequency of Contact with Children	
	Per cent seeing children less than weekly (N = 47)	Per cent seeing children weekly or oftener (N = 98)
Neglect	30	13
No Neglect	70	87
Total	100	100

Note.—Sixteen subjects excluded because of insufficient data. $X^2 = 5.05$. $P < .05$.

TABLE 2. RELATIONSHIP BETWEEN EXPRESSED FEELINGS OF NEGLECT AND LIVING ARRANGEMENTS.

Expressed Feelings of Neglect by Family	Per cent not living with children, but seeing them weekly or oftener (N = 51)	Per cent living with children (N = 47)
Neglect	8	19
No Neglect	92	81
Total	100	100

$X^2 = 1.823$. $P > .1$.

Further investigation of these two variables revealed that expressed feelings of neglect were related to frequency of contact with children only among the upper status subjects. The subjects' social status positions were obtained by use of Warner's "Index of Status Characteristics" (Warner, Meeker, & Eells, 1957). Arbitrarily, "upper status" individuals were designated as those falling below the median on this continuous variable for the group studied here, and "lower status" individuals as those falling above the median. In Table 3 it can be seen that upper status subjects who had infrequent contacts with their children were more likely to express feelings of neglect than upper status subjects who saw their children more frequently. On the other hand, lower status subjects who had infrequent contacts with their children were not significantly more likely to express feelings of neglect than lower status subjects who saw them more frequently. Thus, within the upper status group of subjects it would appear that there existed an obligation for children to maintain frequent contacts with their parents; and failure to meet this obligation, in large part, accounted for the expression of feelings of neglect by these elderly parents.

Within the group of lower status subjects in our sample variation in expressed feelings of neglect was found to be related to race. Table 4 reveals that lower status Negroes were significantly more likely than lower status whites to express feelings of neglect, while upper status Negroes were no more likely than upper status whites to report such feelings. However, race, in and of itself, is an ambiguous explanatory variable. In accordance with the reasoning above—*i.e.*, expressions of feelings of neglect are produced when expectations for the maintenance of relationships within families are not met—

TABLE 3. RELATIONSHIP BETWEEN EXPRESSED FEELINGS OF NEGLECT AND FREQUENCY OF CONTACT WITH CHILDREN.

Expressed Feelings of Neglect by Family	Upper Status		Lower Status	
	Per cent seeing children less than weekly (N = 27)	Per cent seeing children weekly or oftener (N = 48)	Per cent seeing children less than weekly (N = 17)	Per cent seeing children weekly or oftener (N = 49)
Neglect	30	6	29	20
No Neglect	70	94	71	80
Total	100	100	100	100

Note.—Twenty subjects excluded because of insufficient data.
Upper Status: $X^2 = 5.794$. $P < .02$.
Lower Status: $X^2 = 0.183$. $P > .5$.

it would appear that the observed dependence of expressed feelings of neglect upon race among our lower status subjects could be explained in one of the following ways:

1. Negro-white differences in children's attitudes towards (or expectations of themselves in relation to) their parents: *e.g.*, lower status Negro children are less likely than lower status white children to conform to parental expectations about the maintenance of a relationship between them.

2. Differences in societal contingencies faced by Negro and white children: *e.g.*, lower status Negro children are less able than lower status white children to conform to parental expectations about the maintenance of a relationship between them.

3. Negro-white differences in family structure: *e.g.*, lower status white parents are less likely than lower status Negro parents to have expectations about the maintenance of a relationship between their children and themselves.

Our data indicate that unmet expectations in the lower status group apparently do not relate to frequency of contact with children. Beyond this, however, no data were collected in the present study which bear directly upon either the content of expectations or the congruence between expectations and actual behavior of lower status Negroes and whites.

CONCLUSIONS

The findings of this exploratory study would seem to cast some doubt upon the degree of generality of certain of the present formulations about the older person and his children—*i.e.*, that a high degree of geographical mobility of children, social isolation of older parents, and the changed structure of the family tend to produce feelings of neglect among the elderly. While the presence of social isolation was found to be related to the expression of feelings of neglect, it appeared that this was true only in one segment of our sample—the upper status group. Thus it would appear that social isolation produces feelings of neglect only when there exists an expectation for close parent-child contact.

These factors lead to a tentative reformulation of the position of elderly persons in the kinship system. Although a separate dwelling pattern appears to predominate in urban areas for the most part, we are unable to conclude that intergenerational interdependence has been replaced by independence, isolation, and neglect for the majority of aged persons. Though physically separated to a certain extent, elderly parents and their children may tend to maintain close ties based upon mutual affection and some measure of dependence. Finally, not only have all elderly persons not experienced these general changes attributed to the American family, but also the consequences of such changes, where present, have not been uniform for them. Here again, then, we find that the aged population is not a homogeneous one, a factor which has important implications for action programs and legislation.

It is important to note that evidence is accumulating to lend support to the point of view expressed here. A number of sociologists in recent years have described findings which have challenged the validity of certain of the prevalent stereotypes about older people and their family relationships (Friedman, 1959; Streib, 1958; Thompson, 1959; Townsend, 1957). While these research beginnings are noteworthy, it is suggested that family relations of older people, with special emphasis upon possible variable manifestations, are in need of further careful investigation.

TABLE 4. RELATIONSHIP BETWEEN EXPRESSED FEELINGS OF NEGLECT AND RACE.

Expressed Feelings of Neglect by Family	Upper Status		Lower Status	
	Per cent white (N = 58)	Per cent Negro (N = 20)	Per cent white (N = 34)	Per cent Negro (N = 45)
Neglect	14	15	9	31
No neglect	86	85	91	69
Total	100	100	100	100

Note.—Four subjects excluded because of insufficient data.
Upper Status: $X^2 = 0.057$. $P > .8$.
Lower Status: $X^2 = 4.453$. $P < .05$.

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THE EFFECTS OF AGE ON FACTORIALLY "PURE" MENTAL ABILITIES*

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A review of the literature has revealed an abundance of research on age changes in general intellectual ability, and on highly intercorrelated mental abilities as measured by subtests of general intelligence tests. Very little research, however, has been directed toward the problem of age changes in specific or factorially "pure" mental abilities. What little work has been done has employed Thurstone's Primary Mental Abilities test (PMA) and has used either an aged (Schaie, Rosenthal, & Perlman, 1953; Schaie & Strother, 1955) or an adolescent population (Clark, 1944). Only one investigation has covered most of the lifespan, but in that study only 75 subjects were used (Kamin, 1957). The purpose of the present investigation was to study the relationship between age and performance on eight independent mental abilities using a large sample (N = 634) and covering an age range of 16 to 89 years. Special emphasis was placed on the degree to which these abilities hold up or do not hold up with age.

THE TEST

Because the Thurstone PMA test was designed largely for children, adolescents, and college students, the King Factored Aptitude test was selected for the present study (King, 1953). This test was specifically designed for the adult population working in various jobs in business and industry, and the items are of a type that appeal to adults. It was developed on the basis of factor analysis theory and standardized on a sample of over 16,000 subjects ranging in age from the teens to the seventies. The battery measures eight basic factors of intelligence and is appraised by 14 tests. Only 13 tests were employed in the present investigation (the "Motor" test was not used since it had to be individually administered). Intercorrelations between the tests in the Factored Aptitude Series generally follow the reported intercorrelations of factor-type tests. Lowest intercorrelations are those of the "Motor" test with other tests in the series (.05 to .15); next, between the verbal and non-verbal tests of different factors (.15 to .35); and next, between the verbal tests (.20 to .50). The average intercorrelation between the eight factors is approximately .35. On the basis of these reported intercorrelations, the test constructors maintain that relatively independent or "pure" mental abilities are being appraised. Reliabilities for the different tests range from .89 to .96. Correlations have also been computed between the Factored Aptitude tests and other standardized tests. For example, a correlation of .76 has been found between the "Perception" test and the Minnesota Clerical test. The "Office Terms" test correlates .74 with the Wonderlic Personnel test; and a correlation of .84 is reported between the "Parts" test and the Minnesota Paper Formboard test. In general, it may be said that the tests of the Factored Aptitude battery meet the accepted standards of test construction.

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The King Factored Aptitude test battery was administered to a sample of 634 volunteers ranging in age from 16 to 89 years. The tests were administered either individually (largely with elderly subjects) or to small groups of 2 to 30 people. The subjects were obtained from the following sources: friends, friends of friends, university classes, university extension classes, church groups, and senior citizen clubs. All subjects over the age of 50 years were paid for their services. None of the subjects were institutionalized. As far as occupational background is concerned, the sample (with the exception of those in their teens who were in school) was composed as follows:

1. Professional (lawyers, engineers, librarians, business executives, teachers with academic degrees), 20 per cent.
2. Sub-professional (nurses, teachers without academic degrees, secretaries, stenographers, bookkeepers, salesmen, small business operators), 60 per cent.
3. Skilled labor (carpenters, foremen, furniture makers, electricians, tool designers), 12 per cent.
4. Unskilled labor (caretakers, domestic aids, farm hands, waitresses, laborers), 8 per cent.

Each occupational category was represented, insofar as possible, in approximately the same proportion in each of the various age groups. However, there was a tendency for the higher decades to contain fewer professional people and more of those in the skilled labor category.

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Each answer booklet was scored by the use of the key provided with the test. The raw scores for each test were converted to Z scores and then to T scores, thus enabling direct comparisons of the subjects' performance on the various abilities. Figures 1-5 are plotted in T-score units.

Age changes in "general" intellectual ability. Figure 1 shows that "general" intellectual ability (composite of eight mental abilities) declines progressively from the teens to the 70's. The decline between the teens and the 40's is quite gradual; after the 40's the decline is very steep. Using the 1 per cent level of statistical significance as the criterion, the differences between the teens and the 20's, the 20's and the 30's, and the 30's and the 40's are all statistically significant.

Age changes in specific mental abilities. Figures 2-5 show the relationship between age and

TABLE 1. DISTRIBUTION OF SUBJECTS BY SEX, AGE, AND EDUCATION.

Age Group	Number			Median Age			Mean Years of Schooling	
	M	F	Total	M	F	Total	M	F
Teens	61	82	143	18.4	18.0	18.2	13.1	12.9
20's	115	85	200	24.3	24.2	24.3	13.1	13.0
30's	44	51	95	34.4	34.0	34.2	13.2	12.2
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performance on the eight mental abilities. The figures show that there are really two groups of abilities, those that hold up well with age (comprehension, verbal fluency, numerical ability, and spatial ability) and those that undergo rapid decline (reasoning, memory for names and faces, perception, and dexterity).

Figure 2 indicates that comprehension scores hold up well with age to approximately 45 years, but thereafter show pronounced and uniform decline. The apparent rise from the teens to the 20's is not statistically significant. The decline between 45 and 55 years, as well as the decline after the age of 55, is highly significant.

The age curve for verbal fluency (Fig. 2) closely resembles the one for comprehension. There are no statistically significant differences in scores from the teens to the 30's, nor is the slight increase from the 30's to the 40's significant.

From Figure 3 it is clear that the ability to deal with numbers also shows no decline until the 40's, but thereafter exhibits a sharp and steady decline. The visible rise in the curve with the 20-year-old group is not statistically significant.

In keeping with the three abilities already discussed, spatial ability also remains stable until the 40's, then shows a sharp drop continuing through to the 70's. The small decrease in scores in the 40-year-old group as compared with the 20-year-old group is not satistically significant.

The mental abilities which decline most rapidly with age are reasoning, memory for names and faces, perception, and dexterity. Figure 4 shows that reasoning declines gradually from the teens to the 40's and then declines very steeply thereafter. Both the decreases in scores from the teens to the 20's and from the 20's to the 30's are significant, although the decline from the 30's to the 40's is not.

The memory curve (Fig. 4) shows the same general characteristics as the curve for reasoning ability. The drop in scores between the teens and the 20's, and between the 20's and 30's, is statistically significant, but the decline from the 30's to the 40's is not. Thus it would appear that both reasoning and memory decline from the teens to the 30's, level off to the 40's, and then decline steeply thereafter.

Performance on dexterity and perceptual ability is different from the preceding two abilities in that there is a gradual decline with age with no leveling off at any age. As Figure 5 indicates, the shapes of both curves are quite similar. All differences in scores between the age groups in both mental abilities (except for the difference in dexterity between the teens

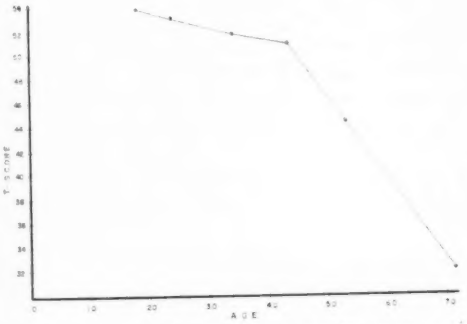

Fig. 1. Age differences in "general" intellectual ability (composite of eight mental abilities).

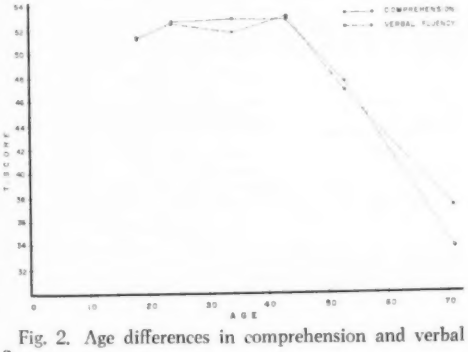

Fig. 2. Age differences in comprehension and verbal fluency.

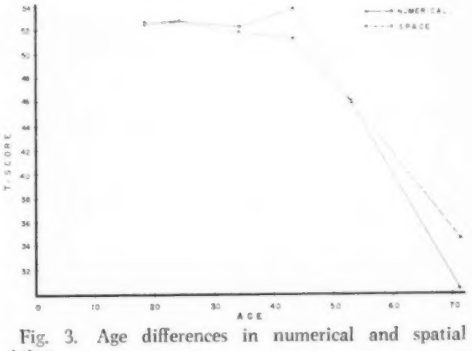

Fig. 3. Age differences in numerical and spatial abilities.

and the 20's) are statistically significant at the .05 level or beyond.

Effect of education on test scores. In any study of age differences it is important to have education as similar as possible for all individuals tested. Since this criterion was not met at the older age levels, i.e., in the 50's and 60's, it was important to determine to what extent difference in education affects subjects' scores on the different tests used in the study. Table 2 shows the correlation between education and scores on each of the eight mental abilities, with age partialled out. In no case was the correlation high. Correlations for perception, dexterity, and numerical ability are especially low. Thus it would appear that the lower educational level of the older subjects is not too important a variable in accounting for the poorer performance of these subjects.

Sex differences. Since the mean educational level of the males and females in the different age groups was very similar (see Table 1) it was thought worthwhile to determine whether any significant sex differences exist in the eight mental abilities. The results show no significant sex difference in dexterity, perceptual ability, verbal fluency, or reasoning. The males showed superior performance on spatial ability, numerical ability, and comprehension. The females showed superior performance only on memory for faces and names.

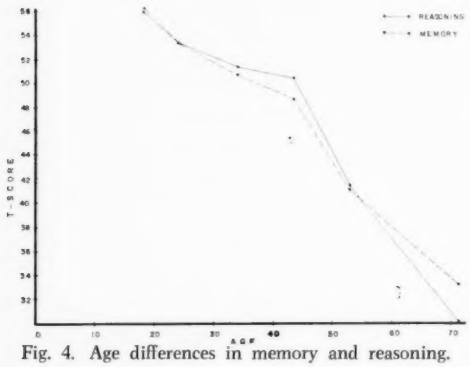

Fig. 4. Age differences in memory and reasoning.

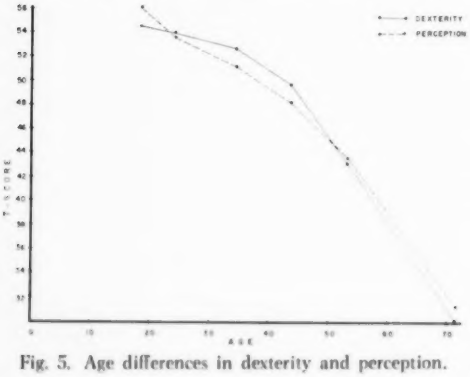

Fig. 5. Age differences in dexterity and perception.

DISCUSSION

"General" intellectual ability. The curve for "general" intellectual ability obtained in this study is quite similar in shape to those obtained for general intelligence when such tests as the Army Alpha (Jones & Conrad, 1933), Weschler-Bellevue (Weschler, 1944) and the Otis (Miles & Miles, 1932) have been used. There is one main difference; in the present investigation the decline from the teens to the 40's is much less pronounced than in these other studies. This apparent discrepancy is perhaps due to differences in the types of abilities being appraised. In the present experiment, overall performance on eight factorially "pure" mental abilities was measured, while in the other studies intelligence was measured by such tests as the Wechsler. Some differences would therefore be expected.

The curve obtained in the present study is also quite similar in shape to those obtained in studies on other kinds of intellectual processes. For example, Raven (1948), studying subjects ranging in age from 6 to 60 years, found that the "capacity to understand and apply a fresh method of thinking" reaches a peak in the mid-twenties and then slowly declines thereafter. A similar curve was obtained by Bromley (1956), who administered the Shaw test to subjects ranging in age from 17 to 82 years. The Shaw test is said to measure creative intellectual output. Bromley found that the peak for both quality and quantity of output occurred in the youngest group, and that both quality and quantity declined gradually thereafter, with the quality of output decreasing more rapidly. All

Table 2. Correlations between Education and Scores on Mental Abilities with Age Partialled Out.

Mental Ability	*r*
Memory	.20
Perception	.25
Dexterity	.29
Numerical	.37
Reasoning	.37
Comprehension	.37
Space	.40
Fluency	.42

of these studies, including the present one, indicate that the relationship between age and performance is very similar for the various kinds of intellectual processes.

One of the main findings of the present study was that the pattern of decline varied for the eight mental abilities. This differential pattern of decline is in line with findings from other studies. For example, Kamin (1957), using the PMA, found that verbal fluency, verbal meaning, and numerical ability held up much better with age than did reasoning and spatial ability. Essentially similar results were obtained by Schaie *et al.* (1953), who also used the PMA.

This differential pattern of decline is also supported by performance on individual subtests of intelligence tests. For example, Jones and Conrad (1933), using the Army Alpha, found that scores on verbal analogies declined more quickly than those on arithmetical reasoning, and the latter declined more quickly than those on general information. Likewise, Wechsler (1944) observed that scores on the information, comprehension, and similarities subtests of the Wechsler test held up much better with age than the scores on the block assembly, arithmetic, and digit span subtests. Berkowitz (1953), who also used subtests of the Wechsler, found a similar pattern. It should be remembered, however, that these studies are not appraising specific or "primary" mental abilities but merely performance on subtests of intelligence tests which are usually highly intercorrelated. Despite this fact, it is clear that the specific effect of age on intellectual processes is a function of the particular abilities being studied.

The individual mental abilities. The abilities which were found to hold up well with age (up to the 40's) will be discussed first.

The present results on comprehension are in keeping with those of other studies. The comprehension test of the Wechsler scale has been examined by several investigators, including Wechsler himself, and there is general agreement that it is one of the "hold" tests (Corsini & Fassett, 1953; Wechsler, 1944). Similarly, Kamin (1957) found that the performance on the verbal meaning test of the PMA battery holds up well with age. The studies of vocabulary are also relevant here because the comprehension test of the present study was made up largely of vocabulary items. There is again a general agreement that vocabulary level remains constant over most of the lifespan (Babcock, 1930; Fox, 1947; Weisenberg & McBride, 1936).

Few age studies are available on verbal fluency. Kamin (1957) found this ability, as did the present investigators, to be fairly stable. As already mentioned, vocabulary shows little change with age and, since fluency depends partly, at least, on vocabulary, this further supports the present findings.

Our findings on numerical ability are in line with Kamin's (1957). Other relevant experiments, however, report an early and progressive decline with age in this ability. Jones and Conrad (1933), for example, reported that numerical ability began to decline in the 20's, with numerical completions showing a greater decrement than arithmetic problems. Wechsler (1944) placed his arithmetic subtest under the "don't hold" category. Other studies employing the arithmetic subtest of the Wechsler have also reported an early decline in performance (Berkowitz, 1953; Hunt, 1949). In accounting for these apparently contradictory results, it should be remembered that the Numbers test of the Factored Aptitude battery is composed entirely of quite simple problems of addition, subtraction, multiplication and division. Furthermore, the right answer is shown, and the subject merely has to select the correct answer out of four possible ones. The numerical test of the PMA also consists entirely of addition and multiplication problems. On the other hand, the arithmetic tests of the Wechsler and of the Army Alpha used by Jones and Conrad involve the solution of worded and numerical problems, often of some difficulty and of a type requiring some reasoning ability. This difference in the type of numerical ability being appraised in the two sets of studies is probably the main factor responsible for the discrepancy.

Spatial ability is the last of the four abilities which were found to hold up with age. This finding however, is contrary to the results obtained by others. Kamin (1957), using the space test of the PMA battery, found this ability to be one of those that does not hold up well. This discrepancy again is likely due to differences in the types of tests used. The spatial ability of the Factored Aptitude battery is measured by three different tests appraising both two- and three-dimensional aspects, while the PMA spatial ability test is largely of the two-dimensional variety. The other relevant studies

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THE EFFECTS OF AGE ON FACTORIALLY "PURE" MENTAL ABILITIES*

I. BILASH, M.A., AND JOHN P. ZUBEK, Ph.D.
(Department of Psychology, University of Manitoba, Winnipeg, Canada)

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From Figure 3 it is clear that the ability to deal with numbers also shows no decline until the 40's, but thereafter exhibits a sharp and steady decline. The visible rise in the curve with the 20-year-old group is not statistically significant.

In keeping with the three abilities already discussed, spatial ability also remains stable until the 40's, then shows a sharp drop continuing through to the 70's. The small decrease in scores in the 40-year-old group as compared with the 20-year-old group is not satistically significant.

The mental abilities which decline most rapidly with age are reasoning, memory for names and faces, perception, and dexterity. Figure 4 shows that reasoning declines gradually from the teens to the 40's and then declines very steeply thereafter. Both the decreases in scores from the teens to the 20's and from the 20's to the 30's are significant, although the decline from the 30's to the 40's is not.

The memory curve (Fig. 4) shows the same general characteristics as the curve for reasoning ability. The drop in scores between the teens and the 20's, and between the 20's and 30's, is statistically significant, but the decline from the 30's to the 40's is not. Thus it would appear that both reasoning and memory decline from the teens to the 30's, level off to the 40's, and then decline steeply thereafter.

Performance on dexterity and perceptual ability is different from the preceding two abilities in that there is a gradual decline with age with no leveling off at any age. As Figure 5 indicates, the shapes of both curves are quite similar. All differences in scores between the age groups in both mental abilities (except for the difference in dexterity between the teens

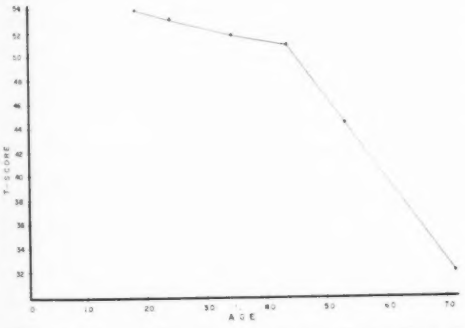

Fig. 1. Age differences in "general" intellectual ability (composite of eight mental abilities).

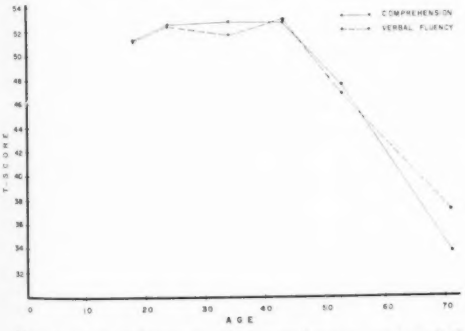

Fig. 2. Age differences in comprehension and verbal fluency.

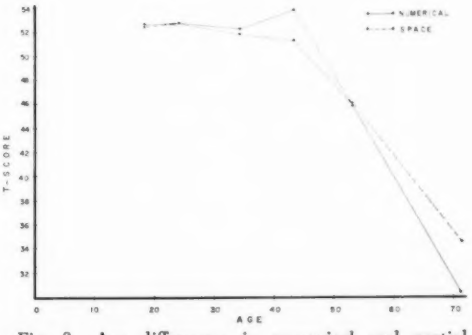

Fig. 3. Age differences in numerical and spatial abilities.

and the 20's) are statistically significant at the .05 level or beyond.

Effect of education on test scores. In any study of age differences it is important to have education as similar as possible for all individuals tested. Since this criterion was not met at the older age levels, i.e., in the 50's and 60's, it was important to determine to what extent difference in education affects subjects' scores on the different tests used in the study. Table 2 shows the correlation between education and scores on each of the eight mental abilities, with age partialled out. In no case was the correlation high. Correlations for perception, dexterity, and numerical ability are especially low. Thus it would appear that the lower educational level of the older subjects is not too important a variable in accounting for the poorer performance of these subjects.

Sex differences. Since the mean educational level of the males and females in the different age groups was very similar (see Table 1) it was thought worthwhile to determine whether any significant sex differences exist in the eight mental abilities. The results show no significant sex difference in dexterity, perceptual ability, verbal fluency, or reasoning. The males showed superior performance on spatial ability, numerical ability, and comprehension. The females showed superior performance only on memory for faces and names.

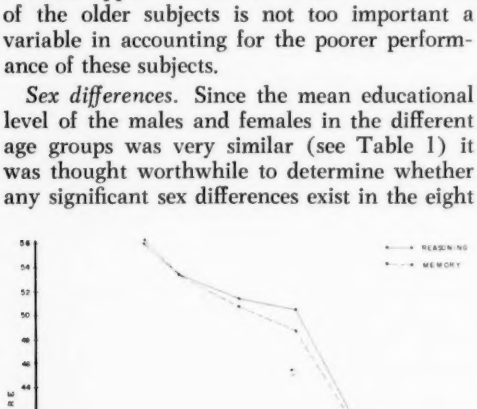

Fig. 4. Age differences in memory and reasoning.

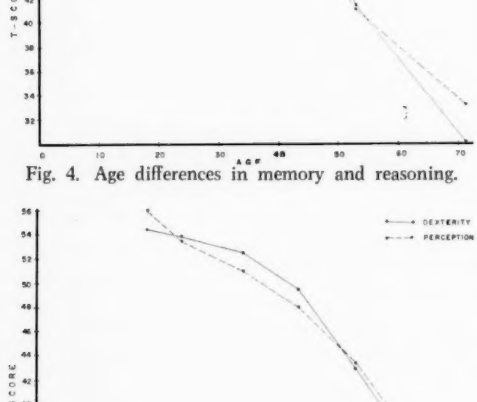

Fig. 5. Age differences in dexterity and perception.

DISCUSSION

"General" intellectual ability. The curve for "general" intellectual ability obtained in this study is quite similar in shape to those obtained for general intelligence when such tests as the Army Alpha (Jones & Conrad, 1933), Weschler-Bellevue (Weschler, 1944) and the Otis (Miles & Miles, 1932) have been used. There is one main difference; in the present investigation the decline from the teens to the 40's is much less pronounced than in these other studies. This apparent discrepancy is perhaps due to differences in the types of abilities being appraised. In the present experiment, overall performance on eight factorially "pure" mental abilities was measured, while in the other studies intelligence was measured by such tests as the Wechsler. Some differences would therefore be expected.

The curve obtained in the present study is also quite similar in shape to those obtained in studies on other kinds of intellectual processes. For example, Raven (1948), studying subjects ranging in age from 6 to 60 years, found that the "capacity to understand and apply a fresh method of thinking" reaches a peak in the mid-twenties and then slowly declines thereafter. A similar curve was obtained by Bromley (1956), who administered the Shaw test to subjects ranging in age from 17 to 82 years. The Shaw test is said to measure creative intellectual output. Bromley found that the peak for both quality and quantity of output occurred in the youngest group, and that both quality and quantity declined gradually thereafter, with the quality of output decreasing more rapidly. All

Table 2. Correlations between Education and Scores on Mental Abilities with Age Partialled Out.

Mental Ability	r
Memory	.20
Perception	.25
Dexterity	.29
Numerical	.37
Reasoning	.37
Comprehension	.37
Space	.40
Fluency	.42

of these studies, including the present one, indicate that the relationship between age and performance is very similar for the various kinds of intellectual processes.

One of the main findings of the present study was that the pattern of decline varied for the eight mental abilities. This differential pattern of decline is in line with findings from other studies. For example, Kamin (1957), using the PMA, found that verbal fluency, verbal meaning, and numerical ability held up much better with age than did reasoning and spatial ability. Essentially similar results were obtained by Schaie *et al.* (1953), who also used the PMA.

This differential pattern of decline is also supported by performance on individual subtests of intelligence tests. For example, Jones and Conrad (1933), using the Army Alpha, found that scores on verbal analogies declined more quickly than those on arithmetical reasoning, and the latter declined more quickly than those on general information. Likewise, Wechsler (1944) observed that scores on the information, comprehension, and similarities subtests of the Wechsler test held up much better with age than the scores on the block assembly, arithmetic, and digit span subtests. Berkowitz (1953), who also used subtests of the Wechsler, found a similar pattern. It should be remembered, however, that these studies are not appraising specific or "primary" mental abilities but merely performance on subtests of intelligence tests which are usually highly intercorrelated. Despite this fact, it is clear that the specific effect of age on intellectual processes is a function of the particular abilities being studied.

The individual mental abilities. The abilities which were found to hold up well with age (up to the 40's) will be discussed first.

The present results on comprehension are in keeping with those of other studies. The comprehension test of the Wechsler scale has been examined by several investigators, including Wechsler himself, and there is general agreement that it is one of the "hold" tests (Corsini & Fassett, 1953; Wechsler, 1944). Similarly, Kamin (1957) found that the performance on the verbal meaning test of the PMA battery holds up well with age. The studies of vocabulary are also relevant here because the comprehension test of the present study was made up largely of vocabulary items. There is again a general agreement that vocabulary level remains constant over most of the lifespan (Babcock, 1930; Fox, 1947; Weisenberg & McBride, 1936).

Few age studies are available on verbal fluency. Kamin (1957) found this ability, as did the present investigators, to be fairly stable. As already mentioned, vocabulary shows little change with age and, since fluency depends partly, at least, on vocabulary, this further supports the present findings.

Our findings on numerical ability are in line with Kamin's (1957). Other relevant experiments, however, report an early and progressive decline with age in this ability. Jones and Conrad (1933), for example, reported that numerical ability began to decline in the 20's, with numerical completions showing a greater decrement than arithmetic problems. Wechsler (1944) placed his arithmetic subtest under the "don't hold" category. Other studies employing the arithmetic subtest of the Wechsler have also reported an early decline in performance (Berkowitz, 1953; Hunt, 1949). In accounting for these apparently contradictory results, it should be remembered that the Numbers test of the Factored Aptitude battery is composed entirely of quite simple problems of addition, subtraction, multiplication and division. Furthermore, the right answer is shown, and the subject merely has to select the correct answer out of four possible ones. The numerical test of the PMA also consists entirely of addition and multiplication problems. On the other hand, the arithmetic tests of the Wechsler and of the Army Alpha used by Jones and Conrad involve the solution of worded and numerical problems, often of some difficulty and of a type requiring some reasoning ability. This difference in the type of numerical ability being appraised in the two sets of studies is probably the main factor responsible for the discrepancy.

Spatial ability is the last of the four abilities which were found to hold up with age. This finding however, is contrary to the results obtained by others. Kamin (1957), using the space test of the PMA battery, found this ability to be one of those that does not hold up well. This discrepancy again is likely due to differences in the types of tests used. The spatial ability of the Factored Aptitude battery is measured by three different tests appraising both two- and three-dimensional aspects, while the PMA spatial ability test is largely of the two-dimensional variety. The other relevant studies

concern the use of the block design subtest of the Wechsler. In these studies spatial ability is in the "don't hold" category (Corsini & Fassett, 1953; Doppelt & Wallace, 1955; Wechsler, 1944). Again, the apparent discrepancy may lie in the fact that the block design test is a motor rather than a pencil-and-paper test and measures two-dimensional rather than both two- and three-dimensional spatial ability.

Four abilities were found not to hold up with age. As far as reasoning (seeing relationships between words and numbers) is concerned, the present results are largely in keeping with those reported by others. For example, Kamin (1957), using a test of reasoning very similar to the one used in this study, found this ability to be more susceptible to aging than most of the other abilities appraised by the PMA battery. Several other studies employing an analogy type of reasoning test indicate that the decline begins sometime in the 20's (Zubek & Solberg, 1954). As one would expect, however, when more complex reasoning processes are measured, the results are somewhat different. For example, Friend and Zubek (1958), in a study of critical thinking, found that this type of ability holds up to at least the middle thirties. Other kinds of more complex reasoning processes also seem to hold up well with age (Gilbert, 1935; Kuhlen, 1949; Lawton, 1938). Gilbert (1952) suggests that reasoning seems to be especially well maintained where experience is involved, but not when flexibility of thinking is involved. The "Judgment" test of the Factored Aptitude battery which measures reasoning has a rather novel content, and past experience has a rather limited bearing upon it.

The research on memory indicates that the degree to which memory declines with age is dependent upon the nature of the material to be learned (Zubek & Solberg, 1954). When the material involves past experience and knowledge, the decline is relatively slight; when the material is new, the decline is quite pronounced (Eysenck, 1945; Shakow, Dolkart, & Goldman, 1941; Whipple, 1927). The "Memory" test used in the present study requires the subjects to memorize a series of names and faces which are all new to them. Hence our findings are consistent with those of other investigators.

The very early decline in perceptual ability is, in general, supported by other studies. For example, Verville and Cameron (1946) presented a group of incomplete pictures to a group of subjects aged 16 to 56 years. The pictures were flashed on the screen and the time required to identify each figure was recorded. The subjects over the age of 25 required a much longer exposure time to identify the objects than did subjects below this age. Price (1931), also employing a tachistoscopic presentation of perceptual items, observed a decline in the number of items seen after the mid-twenties. Finally, Birren and Botwinick (1955) and Hanes (1953) also reported an early decline in speed of perception.

Dexterity, like perceptual ability, also undergoes a steady but gradual decline with age. This steady decline is supported by the very extensive work of Miles (1931, 1933) on various types of dexterity tasks. Such activities as simple digital extension—flexion speed, speed of rotary motion, manual reach, and grasp—all exhibit an early and gradual decline with age.

The steep decline in performance after the age of 50 on most of the mental ability tests merits further comment. This decline seems to be more pronounced than that reported in other investigations. This difference is probably largely due to two factors, the nature of the sample and the speeded nature of the tests. Differences in educational level among age groups in the sample have already been discussed. Perhaps other sampling variables are also involved. A much more important factor, however, is that of speed. The 13 tests making up the Factored Aptitude battery place a heavy premium on speed. The majority of the tests were of five minutes' duration, and some were as short as one or two minutes. This emphasis on speed is perhaps the most important single factor responsible for the sharp decline after the 50's, for numerous studies have shown that the older person is much more handicapped by time limitations than the younger one in performing psychological tasks (Birren, 1955; Price, 1931).

In conclusion some reference should be made to the sex differences found. In general, these differences conform quite well to those reported by others. For example, it was found that males did better on numerical ability, spatial ability, and comprehension. This male superiority in numerical ability is supported by the results of the numbers test of the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1951), of the Army Alpha (Whipple, 1927), and of several other studies (Anastasi & Foley, 1949). Similarly, there is an impressive body of evidence in favor of superior male performance on

various space relations tests, including the space test of Thurstone's PMA battery and of the Differential Aptitude Test (Anastasi & Foley, 1949; Bennett *et al.*, 1951; Hobson, 1947). As far as comprehension is concerned, a better performance by the males might be expected, since two of the three tests measuring this ability appraised mechanical knowledge and knowledge of the sales field—a content undoubtedly of more interest to men than to women. Only the third test ("Office Information") contained material that might be of equal or of more interest to women.

On only one ability test did the females clearly out-perform the males—memory for faces and names. This is in keeping with the findings that women excel in most tests of memory (Anastasi & Foley, 1949), although the direction of sex differences often depends upon the relative appeal of the content for the two sexes. In the present case the superiority of the females may be due to their greater interest in facial appearance. A review of the literature by Anatasi and Foley (1949) indicated that women, in general, also do better on three other abilities, viz., perceptual, manual dexterity, and verbal. In the present study the women scored higher on the first two abilities, although the differences were not quite statistically significant. The almost identical scores received by the two sexes on verbal fluency is puzzling in view of the impressive body of evidence in favor of female superiority in verbal or linguistic functions (Anastasi & Foley, 1949). However, this clearcut superiority may apply only to more complex verbal abilities and not to those simpler ones appraised by our fluency test. This view is supported to some degree by two studies on older children in which the fluency test of the Thurstone PMA battery was used—a test very similar to the test employed in this study. In one of these studies (Hobson, 1947) the girls were clearly superior, while in the other (Havighurst & Breese, 1947) there was no significant difference. Furthermore, granted that sex differences in verbal fluency may exist in childhood, they may not exist in the adult population.

No significant sex differences were observed for the test of reasoning ability. This test is made up almost exclusively of verbal series and numerical sequences in almost equal proportions. In view of what has already been stated about the general superiority of females on verbal problems and of males on numerical problems, these differences may have cancelled out and thus led to an absence of an overall sex difference in this test.

It is clear from this discussion that the sex differences observed in this study conform, in general, quite closely to those reported by other investigators. Where differences occur, they may be attributed to differences in types of tests used and to sampling variations.

SUMMARY

The King Factored Aptitude test was administered to a group of 634 subjects ranging in age from 16 to 89 years and representing diverse educational, occupational, and economic backgrounds. This test battery measures eight independent or factorially "pure" abilities; comprehension, verbal fluency, space relations, numerical ability, memory for faces and names, reasoning, dexterity, and perception. The main findings were:

1. "General" intellectual ability, a composite of the eight mental abilities, showed a progressive decline from the teens to the 70's.

2. Comprehension, verbal fluency, numerical, and spatial abilities held up very well with age to the mid-forties but declined thereafter.

3. Reasoning, memory, perception, and dexterity did not hold up with age but declined gradually from the teens to the 70's.

4. Males showed a significantly better performance on comprehension, numerical ability, and spatial ability, while females were significantly better on memory. No significant sex differences were found for reasoning, verbal fluency, perception, and dexterity.

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THE AGING DIMENSION: A FACTORIAL ANALYSIS OF INDIVIDUAL DIFFERENCES WITH AGE ON PSYCHOLOGICAL AND PHYSIOLOGICAL MEASUREMENTS*

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There is now a considerable amount of information available on physiological, personality and ability changes with age. But as yet little is known of how these specific changes relate to one another. It is possible that the well-known age decline in scores on speeded ability tests is the expression of a wider aging dimension with physiological and temperamental components. It is just as possible to conclude from the information available at present that aging occurs along two or more distinct dimensions in which, for example, the decline in ability and the changes in such physiological measures as blood pressure are unrelated. The present investigation, a factor analytic study of some physiological, ability, and personality measures which change with age, was designed to explore such possibilities.

METHOD

The 25 variables which were factor analyzed are listed below in the order in which they appear later in the matrices.

1. Age. In years.
2. Sex. Male=1, female=2, for the computation of point-biserial correlations.
3. Spatial ability. The Space subtest from Thurstone's Primary Mental Abilities (PMA) battery (Thurstone & Thurstone, 1947).
4. Reasoning ability. The Reasoning subtest from the PMA battery.

Variables 3 and 4 are the subtests of the PMA which have shown the severest deficits with age (Kamin, 1957; Schaie, Rosenthal, & Perlman, 1953).

Variables 5 to 11 are from Cattell's Objective-Analytic Personality Test Battery (Cattell, 1955). In a previous, unrelated study (Clark, 1958), 82 tests from the Cattell battery were administered to 40 males ranging in age from 20 to 65 years. The seven tests chosen for analysis in the present study were those that correlated most highly with age.

5. Absence of questionable preferences in reading (Master Index number[1] 21). This test consisted of 15 pairs of fictitious book titles accompanied by short descriptions of the contents. One of each pair of books was of a "serious, morally desirable character"; the other was "cheap, sensational, criminal." The subject *(S)* was required to make a forced choice of that one of each pair he would prefer to read. The score was the number of unsensational preferences. This test had correlated positively with age.
6. Responsiveness of aspiration level to performance on a coding task (MI 145). This test consisted of five similar coding tasks. After each task *S*, having knowledge of his results, was asked to estimate how well he would do on the next task. The score was computed by the formula
$$\Sigma\ (E_t - E_{t-1}) - (A_{t-1} - A_{t-2}),$$
where E_t is the estimated number of codings to be accomplished on task t, E_{t-1} is the estimated number of codings to be accomplished on the task preceding t, A_{t-1} is the number of codings accomplished on task $t-1$, and A_{t-2} is the number of codings accomplished on the task preceding $t-1$. A high score indicated low responsiveness. Test 6 had correlated negatively with age (that is, older *Ss* had higher responsiveness).
7. Speed of letter comparison (MI 307). This was a test of perceptual speed of matching groups of letters. The score was the number of pairs of letter groups matched regardless of whether they were matched correctly or incorrectly. As with most speed tests, this test had correlated negatively with age.
8. Carping criticisms and mischievous humor (MI 29). This test consisted of two subtests. In the first, *S* was asked to mark his agreement or disagreement with statements critical of tests he had done. In the other, *S* was asked which of 7 pairs of jokes he considered funnier, one of each pair being sadistic or mischievous. The score was the sum, in standard scores, of criticisms in the first part and sadistic or mischievous choices in the second. The correlation with age had been negative.
9. Ratio of accomplished items to inaccuracy at maximum speed on a rapid cancellation task

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[1] The Master Index number (M I) identifies the test in the *Encyclopedia of Tests* at the Laboratory of Personality Assessment and Group Behavior, University of Illinois, and is the number by which the test has been designated in a series of papers from that laboratory.

(MI 120a). The score was the number of cancellations divided by the number of incorrect cancellations. This measure had correlated negatively with age.

10. Ratio of retrovert to antevert association (MI 110). *S* listed in four 2-minute periods short phrases on (a) pleasant memories, (b) unpleasant anticipations, (c) unpleasant memories, and (d) pleasant anticipations. The score was the ratio of the total number of memories listed to the total number of anticipations listed; that is, (a)/(d) plus (c)/(b). This measure had correlated positively with age.
11. Ratio of emotional to non-emotional recall (MI 25). This was a test of immediate memory for sets of phrases, some of which were emotional (e.g., "the bloody dress of tragedy"), some dry (e.g., "the man was thirty-five"). The score was the ratio of the number of emotional phrases recalled to non-emotional phrases recalled. The correlation with age had been positive, older people recalling relatively more emotional phrases.
12. Amount of immediate recall. The material for this test was the same as for test 11. The score was the number of phrases (emotional and non-emotional) correctly recalled. This had correlated negatively with age.
13. Attitude to religion. This was a Likert-type attitude scale of 19 items, devised for this study.
14. Attitude to old age. This Likert-type attitude scale consisted of 24 items expressing positive or negative feelings about the later years of life. It was devised for this study.
15. Systolic blood pressure. This was measured both at the beginning and at the end of the individual testing session and the lowest of the two values used.
16. Hand strength. A Collins squeeze dynamometer was used. This dynamometer was not adjustable to hand size. Right and left hand values were averaged.
17. Reaction time. The apparatus consisted of five telegraph keys, each with a small light bulb directly above. Following ready signals, the experimenter switched the bulbs on in random order and *S* raised his preferred hand from its original position to depress the key beneath the light. The score was the average latency between the onset of the light and the depression of the appropriate key.
18. Sound threshold. The method of limits was used to estimate an "absolute threshold" for a tone of 3,000 cycles per second. The tone was delivered by earphones to both ears.
19. Accommodation of the lens of the eye. The threshold of the convex focusing power of the lens was estimated by the method of limits. One end of a metal tape was held an inch below *S*'s eye and the tape extended horizontally. *S* focussed on a one-half inch tall letter "A" printed on a card which was moved along the tape. The near-points at which the outlines of the "A" were reported to blur or clear were recorded and these data averaged for both eyes.
20. Word-association latency. *S* was instructed to respond with the first word that came to mind following a word read to him by the experimenter. The experimenter used a list of 20 common words. The score was the average latency between the termination of the experimenter's voice and the onset of *S*'s reply.
21. Self estimate of the degree of fear of death. *S* was asked to rate the degree of his fear of death on a five-point scale.
22. Errors on maze tasks. The maze apparatus[2] essentially consisted of 20 rows of 20 numbered contact points fixed on a board, and a stylus to be held by *S* which, when placed on a contact point, could close a circuit activating a buzzer. Using the stylus, *S* was to find his way through the matrix of contact points along paths of varying complexity which could be formed by deactivating series of the contact points. A correct move, then, was made when *S* placed the stylus on a contact point without activating the buzzer. *S* could obtain either a numerical or a spatial clue to each maze. Five mazes of graded difficulty were used. Variable 22 was the total number of incorrect moves made in performing the maze tasks.
23. Time required for completion of maze tasks. The apparatus is described above.
24. Socio-economic status[3]. Type of work (or husband's type of work in the case of housewives) was rated on an eight-point scale.
25. Anomy scale. Durkheim's concept of *anomie* denotes a state of social disorganization, nonparticipation and normlessness. The scale used here was developed by Srole (1956) and consists of statements expressing the attitudes corresponding to the *anomie* social situation. High social mobility and social isolation correlated significantly with the anomy scale in a study by Bell (1957).

The Ss were 102 males and females selected from a larger number who had responded to advertisements promising payment for their services. There were approximately 10 males and 10 females in each age decade from 20 to 70 years. Ss in each of the five decades were matched on the socio-economic rating scale (the correlation between age and the socio-economic ratings was −.01). The distribution of socio-economic status was wide, with approximately the same number in each of the categories (there were no Ss in the lowest category).

The tests were given in two sessions lasting about two hours each. In the first session

[2] The writer is grateful to Mr. M. Eveson and Dr. G. Mangan, who constructed the maze apparatus, and to Mr. W. Newman, who tested the Ss.

[3] Thanks are due to Dr. A. Kapos for rating socio-economic status, and for scoring the anomy scale.

TABLE 1. THE ORIGINAL CORRELATION MATRIX FOR TWENTY-FIVE VARIABLES.

Variable No. [a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	(67)																								
2	01	(81)																							
3	−42	25	(57)																						
4	−49	−04	57	(59)																					
5	51	−18	−22	−24	(51)																				
6	−28	−23	−02	20	−13	(36)																			
7	−45	−22	34	53	−05	24	(73)																		
8	−31	10	09	01	−25	−03	10	(31)																	
9	−47	−25	36	53	−16	36	73	09	(73)																
10	21	−05	−15	−19	18	−08	−10	−14	−13	(33)															
11	22	−05	−14	−31	12	−12	−24	−01	−09	−11	(31)														
12	−40	−01	40	59	−14	14	53	−03	47	−14	−31	(59)													
13	25	−11	−21	−28	13	−01	−06	−02	−15	08	03	−07	(38)												
14	06	03	20	01	18	12	10	−05	00	−09	−11	−02	−38	(38)											
15	65	15	−20	−31	36	−21	−32	−20	−36	20	19	−27	22	08	(65)										
16	−21	81	36	07	−25	−06	−12	14	−08	−14	−04	08	−32	05	04	(81)									
17	52	−34	−54	−45	22	−09	−55	−19	−41	16	08	−40	24	−14	29	−51	(55)								
18	57	25	−24	−43	27	−34	−31	02	−33	07	22	−26	21	13	50	12	24	(57)							
19	67	12	−30	−38	34	−25	−32	−14	−32	03	17	−26	22	01	36	−04	38	53	(67)						
20	42	−09	−28	−33	37	−20	−27	−11	−26	22	28	−25	−08	−07	33	−16	27	28	28	(42)					
21	−35	12	20	19	−28	−05	10	18	19	−21	17	10	−14	−13	−18	14	−27	−18	−27	−19	(35)				
22	33	−04	−46	−48	21	−19	−21	−11	−32	17	19	−38	01	−11	18	−11	33	23	18	25	−14	(75)			
23	34	−18	−51	−50	11	−14	−28	−11	−44	09	18	−39	05	−11	10	−28	46	15	23	25	−15	75	(75)		
24	−01	−21	17	46	01	18	19	−20	24	−13	−16	38	−27	−03	−05	−11	−17	−28	−08	−04	−05	−34	−19	(46)	
25	34	−20	−38	−38	14	−09	−23	04	−21	33	16	−28	06	−03	26	−18	35	25	18	21	01	28	27	−18	(38)

NOTE.—Decimals omitted throughout.

[a] The measures to which the variable numbers refer are described in the "Method" section of the text.

groups of 20 or more Ss were given those tests which could be administered to a group. The second session was devoted to individual testing.

RESULTS

Analysis of the Data

The correlations between the 25 variables are shown in Table 1. All are product moment correlations except those involving variable 2 (sex) which are point-biserial correlations.

Five factors were extracted from the matrix by the complete centroid method. Tucker's phi criterion for sufficient extraction of factors (Fruchter, 1954) was exceeded on the fourth residual matrix. The centroid factor matrix is shown in Table 2.

The five factors were rotated toward simple structure by Thurstone's Single Plane Method (Thurstone, 1947). A general factor proved to be necessary if a large proportion of the variance was not to be eliminated in the rotated factor matrix. Since the positioning of a general factor is indeterminant due to the lack of a hyperplane, the other four factors were rotated to simple structure and the general factor then placed approximately orthogonally to the others.

TABLE 2. THE CENTROID FACTOR MATRIX: RAW FACTOR LOADINGS.

Variable	F1	F2	F3	F4	F5	h^2
1. Age	79	10	41	05	04	81
2. Sex	−16	77	15	21	−34	80
3. Spatial Ability	−66	21	26	06	09	55
4. Reasoning ability	−74	−18	23	19	20	71
5. Reading preference	45	−11	41	−08	15	41
6. Aspir. level responsiveness	−29	−38	−06	−09	−11	25
7. Letter comparison speed	−58	−41	23	−25	12	64
8. Critical-aggressiveness	−20	20	−27	−28	−06	23
9. Accomplished/inaccuracy	−61	−33	09	−29	26	64
10. Retro/antevert associations	31	−15	13	14	11	17
11. Emotional/nonemotional recall	30	27	−19	−25	31	36
12. Immediate recall	−59	−21	31	10	07	51
13. Attitude to religion	27	−14	15	−40	−31	37
14. Attitude to old age	−04	−07	34	−31	−32	31
15. Systolic blood pressure	53	22	39	04	08	49
16. Hand strength	−36	73	04	19	−25	77
17. Reaction time	71	−21	−17	08	−05	59
18. Sound threshold	52	40	28	−20	−11	56
19. Lens accommodation	57	21	31	−09	−11	48
20. Word-association latency	50	08	12	08	29	36
21. Fear of death	−31	20	−32	−13	27	33
22. Maze errors	59	−12	−24	17	−12	47
23. Maze time	61	−20	−37	24	−19	64
24. Socio-economic status	−29	−19	23	25	30	33
25. Anomy	46	−05	−13	−11	17	27
Average % variances accounted for	24.6	9.1	6.6	3.8	4.1	

NOTE.—Decimals omitted throughout.

The transformation matrix is shown in Table 3, the rotated factor matrix in Table 4, and the matrix of correlations between factors in Table 5.

Interpretation of the Factors

As seen in Table 4, Factor 1, the aging factor, accounts for an average of 20.6% of the variances and for almost all the variance of age. After age, three physiological-decline measures (Variables 15, 19, 18) have the highest saturations. (The failure of hand strength to load higher than −.22 may be due to measurement with a dynamometer unadjustable to hand size which put the major proportion of its variance on the sex factor.) An attitude scale, absence of questionable reading preferences, achieved a surprisingly high loading of .57. This presumably reflects a decreasing interest in accounts of sex and violence with age—or, at least, a decrease in expressed interest. The measures of ability and speed all have medium saturations on the aging factor.

As seen in Column 2 of Table 4, Factor 2 is a second-order ability factor on which all the power and speed measures load. Its significance is that it is approximately orthogonal to the aging factor and that age has an approximately zero loading on it. There appears to be a dimension of general ability which is quite independent of the dimension which maximizes age and physiological decline.

The other three factors are of little interest in connection with aging. Factor 3 is clearly a sex factor, Factor 4 appears to be a "personality stability" factor, and Factor 5 has been tentatively interpreted as "tough mindedness."

Table 3. The Transformation Matrix.

	I	II	III	IV	V
I_o	88	47	−03	−25	00
II_o	11	−05	78	−45	−03
III_o	46	−66	−03	49	−11
IV_o	06	36	50	62	72
V_o	04	−45	−38	−33	69

Table 4. The Rotated Factor Matrix.

Variable	F1	F2	F3	F4	F5
1. Age	90	10	05	−02	02
2. Sex	01	02	84	01	−12
3. Spatial ability	−43	−51	17	21	07
4. Reasoning ability	−55	−51	−11	43	26
5. Reading preference	57	−15	−21	04	00
6. Aspir. level responsiveness	−33	−06	−29	20	−12
7. Letter comparison speed	−46	−55	−48	25	−11
8. Critical-aggressiveness	−30	00	05	−33	−22
9. Accomplished/inaccuracy	−54	−55	−49	08	−03
10. Retro/antevert associations	33	07	−10	10	17
11. Emotional/nonemotional recall	20	02	−04	−54	05
12. Immediate recall	−39	−47	−13	43	09
13. Attitude to religion	25	03	−20	−08	−51
14. Attitude to old age	08	−21	−10	12	−48
15. Systolic blood pressure	68	−04	13	−04	03
16. Hand strength	−22	−05	77	−02	−06
17. Reaction time	53	51	−12	−10	05
18. Sound threshold	61	02	23	−26	−26
19. Lens accommodation	66	07	13	−11	−18
20. Word association latency	52	05	−03	−15	24
21. Fear of death	−40	−11	01	−25	12
22. Maze errors	40	56	03	−07	07
23 Maze time	35	71	03	−03	09
24. Socio-economic status	−14	−32	−14	33	36
25. Anomy	34	19	−17	−28	05
Average % variances accounted for	20.6	10.7	8.7	5.3	4.1

Note.—Decimals omitted throughout.

SUMMARY AND CONCLUSIONS

A battery of 25 physiological, ability and personality measures, most of which were expected to vary with age, were administered to a sample of 102 males and females evenly covering the age span of 20 to 70 years. Five factors were extracted from the 25 x 25 correlation matrix by the centroid method and rotated into an approximation to oblique simple structure.

A single general aging factor was obtained, loading 19 of the 25 measures and accounting for almost all the variance of age. It was not possible to break this general factor down, that is, to unload more of its variance onto the minor factors. We must conclude that, at the level of this analysis, aging occurs along a single dimension, measured best by blood pressure, lens accommodation and sound threshold and less well by ability and speed tests.

Factor 2 lent credence to the generality of the aging factor. Factor 2 was an unambiguous general ability factor approximately orthogonal to the aging factor and having no age loading.

Table 5. Matrix of Correlations Between Factors.

	I	II	III	IV	V
I	1.00	.11	.06	−.02	.02
II	.11	1.00	.32	−.05	.02
III	.06	.32	1.00	.08	.08
IV	−.02	−.05	.08	1.00	.18
V	.02	.02	.08	.18	1.00

Because of the lack of a hyperplane, the positioning of the aging factor was inexact. A further factor analysis should include a sufficient amount of variance in the hyperplane to enable the rotation of the aging factor to a unique position.

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RORSCHACH RIGIDITY AND SENSORY DECREMENT IN A SENESCENT POPULATION*

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With advancing age the sensory apparatus of the human organism is subject to breakdown or decline in function which may result in serious impairment to the individual's functioning (Covell, 1952; Friedenwald, 1952). It has been contended (Barker, Wright, Meyerson, & Gonick, 1953) that individuals with sensory decrement show regression, withdrawal, and rigidity in interpersonal relationships. In dealing with a senescent group it becomes important, therefore, to evaluate the relationship between visual and auditory changes and personal adjustment.

In attempts to study the personality organization of aged individuals, investigators such as Klopfer (1946), Davidson and Kruglov (1952), Caldwell (1954), and others have turned to the Rorschach as a technique suited for this purpose. Investigators using the Rorschach have attempted to study the personality configuration of aged subjects in homes or institutions for the aged. In these studies results have been frequently analyzed in terms of a mean protocol and discussed as though they represented the Rorschach pattern of aged individuals in general. Often samples are not controlled for intellectual ability, community status, or physical intactness.

Piotrowski (Piotrowski & Lewis, 1950; Piotrowski & Berg, 1955) has discussed the use of the alpha formula as an outgrowth of his theoretical assumptions that, in the typical adult, psychodynamic control is directly proportional to the potential energy which will be elicited in psychosocial situations. In other words, the amount of control over impulses which may be observed in an individual is proportional to the amount of affect which may be generated in that individual. This relationship may be examined through the use of the alpha formula which is limited to adult patients whose Rorschach protocols contain no more than 6 Whole responses and Σ c $\geq \Sigma$ C. According to Piotrowski, persons with high scores tend to manifest little stimulation in interpersonal situations and at the same time show marked rigidity and overcontrol. This control is said to reflect a defense characteristic of patients who realize that their organism is greatly debilitated by some serious disease. Such persons have developed habits of great restraint. Thus, those individuals with high alpha scores are persons who are overcontrolled, underactive and who manifest a withdrawn, rigid approach to the world.

Hypotheses

This study was proposed in an attempt to evaluate the relationship between visual and auditory loss and rigidity, as reflected in Rorschach performance, in a group of socially adjusted elderly individuals. It was hypothesized that:

1. When visual loss was present but corrected to approximate normal vision, there would be no evidence of overcontrol in Rorschach performance. Where visual loss was present but not corrected to approximate normal functioning, an increase in rigidity of Rorschach performance might be anticipated.

2. Subjects with uncorrected hearing decrement would exhibit marked rigidity on the Rorschach.

3. Subjects with both hearing and visual decrement would show a greater amount of Rorschach rigidity than subjects with a major deficit in only one sensory system.

METHOD

Subjects

Subjects were drawn from volunteers who participated in the Duke Geriatrics Research Projects and who had been contacted through religious, fraternal, and civic groups. None were institutionalized. These individuals, all of whom had passed their sixtieth birthdays, were given physical, psychiatric, and psychological

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examinations, including the Rorschach and the Wechsler Adult Intelligence Scale. Visual examinations were conducted by a member of the Ophthalmology Department of the Duke University School of Medicine. In order to study auditory functioning an examination was conducted by an otologist, and a pure tone (MAICO) audiometric study was performed.

Subjects were selected for the six cells in the experimental design according to three categories of far distance vision, and two levels of hearing, as shown in Table 1. The three vision groups included subjects with normal vision (20/15 to 20/40); those with vision corrected to approximate normal; and those with poor functioning vision which was uncorrected. The mean acuity level for the third group was 20/99. The hearing groups were defined according to the mean decibel loss of the better ear in the range 256 to 2048 cps. This range was chosen since it is based upon the range of human conversation. The levels of function were: first, from 0- to 19-decibel loss (mean, 11.1-decibel loss); and second, 21-decibel loss or greater (mean, 39.7-decibel loss).

All subjects received a Full Scale Intellectual evaluation. Based upon WAIS Verbal Scale IQ, only Ss in the Normal range (plus or minus 5 IQ points) were studied in this experiment. All Ss received a neurological examination and those with a history or signs of obvious CNS damage were eliminated.

The N in each of the six cells was 8 (total $N = 48$).

Statistical Analysis

In the scoring of the alpha technique a cutoff of 3 points or more has been established to differentiate high from low scores (Piotrowski & Lewis, 1950; Piotrowski & Berg, 1955.) It is thus possible to utilize a chi-square analysis for studying the frequency distribution of subjects who surpassed this cutoff point. Those subjects whose Rorschach protocols did not meet the requirements for alpha scoring were assigned the score of 0.

When this procedure is adopted, it is necessary to assume only that the alpha scale represents an ordinal scale, but not necessarily an interval scale. Chi-square seemed the appropriate method of analysis for the mitigation of such distortions as might result from utilizing the actual scores.

TABLE 1. VISUAL ACUITY (V_1, V_2, V_3)[a] AND AUDITORY ACUITY (H_1, H_2)[b] FOR EACH OF SIX SUBGROUPS (N FOR EACH SUBGROUP = 8).

	V_1	V_2	V_3
H_1	Normal Vision 20/15 - 20/40	Corrected Vision to 20/15 - 20/40	Poor Vision $20/40^{-2}$ - 20/200
	Normal Hearing 0 - 19 db loss	Normal Hearing 0 - 19 db loss	Normal Hearing 0 - 19 db loss
H_2	Normal Vision 20/15 - 20/40	Corrected Vision to 20/15 - 20/40	Poor Vision $20/40^{-2}$ - 20/200
	Hearing loss 21 db or greater	Hearing Loss 21 db or greater	Hearing Loss 21 db or greater

[a] Vision in better eye.
[b] Hearing in better ear: 256 — 2048 cps. range.

RESULTS

Table 2 Part A shows that there was no significant difference between the distributions of high alpha scores in subjects with normal and subjects with corrected vision. Thus, the results suggest that the wearing of corrective lenses does not seem to result in any special rigidity or impairment of Rorschach performance in aged subjects.

Since there was no difference in performance between Ss with normal and Ss with corrected vision, it was possible to combine these two groups to obtain a group with normal functioning vision, and then to compare this latter group with the group showing visual decrement. Table 2 Part B shows the results of this comparison. The hypothesis that visual decrement would lead to greater rigidity and impaired Rorschach performance was not supported.

Table 2 Part C shows the comparison between subjects with hearing decrement and sub-

TABLE 2. CHI-SQUARE ANALYSIS OF ALPHA SCORES.

Group	Alpha Scores			
	≥ 3	< 3	X^2	p
A: By Normal and Corrected Vision				
Normal Vision	5	11	0	
Corrected Vision	6	10		
B: By Normal Functioning Vision and Visual Decrement				
Normal Functioning Vision	11	21	.533	$> .3$
Visual Decrement	8	8		
C: By Auditory Level				
Normal Hearing	6	18	4.260	$< .05$
Hearing Decrement	13	11		

jects without hearing decrement. Chi-square analysis demonstrates that the incidence of subjects with alpha score 3 or above (the sign of Rorschach rigidity) is greater in the hearing decrement group than in the group with normal hearing. The chi-square is significant at the .05 level.

The test of hypothesis 3 is not presented in tabular form, since it was clear from inspection that there was no difference in the incidence of high alpha scores in the group with both visual and auditory decrement as compared with the other two hearing deficit groups. There were five *Ss* with high alpha scores in the H_2V_3 cell, but four in each of the other two hearing decrement cells (H_2V_1 and H_2V_2). Thus, while it is true that the cell which included *Ss* with multiple deficit showed the greatest incidence of *Ss* with high rigidity scores, this was not statistically different from the incidence of such scores found in the groups showing only hearing decrement.

DISCUSSION

Hearing was chosen as a variable for the present study not only because auditory deficit occurs so frequently with increasing age, but also because of the insidious role defective hearing plays in the impairment of human communication. While the victim of visual loss is usually able to recognize his own condition, personal knowledge of hearing decrement, at least in its early phases, is often received from others. This information is usually associated with frustration and hostility generated by the failure of others to communicate with the "hard of hearing" individual. This study would appear to suggest that the aged individual reacts to hearing loss by withdrawal and by increasing rigidity of personality.

SUMMARY

This study was an investigation of the relationships between visual and hearing decrement and Rorschach indices of rigidity in an aged population. The Rorschach was administered to 48 community volunteers aged 60 and over, divided into 6 groups on the basis of three visual and two auditory levels of functioning. Subjects were screened to eliminate those with neurologically definable CNS damage and those with extreme Verbal IQ scores. Piotrowski's alpha formulation was adopted as an index of extreme overcontrol on the Rorschach. The results indicate:

1. There is no difference in the incidence of high alpha scores between subjects with normal vision, and those with vision which is impaired but functioning normally (through the use of corrective lenses).

2. There are no differences in the incidence of high alpha scores between subjects with normally functioning vision and those with "impaired" vision.

3. There are significant differences in the alpha scores between subjects with normal and subjects with "impaired" hearing.

4. The Rorschach performance of subjects with both vision and hearing impairments is not significantly different from that in subjects showing hearing decrement alone.

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EFFECTS OF POSITION IN A DISPLAY ON PROBLEM-SOLVING ABILITY IN AGED SUBJECTS

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The characteristics of learning by the older adult include a decreasing gradient of efficiency with age, less flexibility in approach, tendencies toward feelings of inferiority and easily evoked anxiety in learning situations, and a greater use of habitual patterns of response (Donahue, 1956). These generalizations have been supported in part in a variety of learning and other performance tasks (Welford, 1951). Shock (1952) has shown that less flexibility may also be found at physiological levels. He hypothesized that aging and death may be due to the decreased ability of the organism to maintain homeostatic conditions. In this regard Welford (1951) and Crook *et al.* (1958) have suggested that deleterious age changes in task performance involve central rather than peripheral processes. Korchin and Basowitz (1956) associate the constricted or rigid cognitive organization noted in most aged subjects when in a new learning situation with anxiety or states of brain pathology.

Some young adults in imposed stress learning tasks respond with poor performance. Some studies have shown that those subjects who do poorest exhibit greater anxiety (Katchmar, Ross, & Andrews, 1958) or less "flexible control" (Klein, 1954). Increasing vulnerability to stress, more group variability in performance, and decreasing efficiency as tasks become more complex, seem to be features most characteristic of older subjects (Birren, 1958; Thorndike, Bergman, Tilton, & Woodyard, 1928).

The present study is a modified replication of an earlier investigation of the effects of position in a display upon problem solving (Kay, 1954). In Kay's study 64 subjects ranging in age from 15 to 72 participated in a problem-solving task consisting of three levels of difficulty. Difficulty was established by varying the position of a coding card in its relation to a display and response board. Kay found that errors increased as difficulty increased, with the oldest age group producing the most errors at each stage. The older subjects experienced greater difficulty in correcting wrong responses, despite immediate information indicating their mistakes. Older subjects maintained incorrect responses over longer periods of time and exhibited less ability to adapt to changes in problem configuration and to shift response patterns than did the younger subjects. These features may be related to the reduced flexibility in receiving, coding, and responding processes thought to be associated with aging.

The present effort was directed toward more intensive study of an aged group. The major purpose was to confirm the error augmentation associated with increasing task difficulty, to determine the relationships between abstract-reasoning ability and problem-solving ability, and to account for possible effects due to the status of visual functioning.

METHODS AND PROCEDURE

Subjects. A group of 29 male Domiciliary members at the Veterans Administration Center, Martinsburg, W. Va., ranging in age from 65 to 77, served as subjects. The group averaged approximately eight years of schooling, ranging from no formal education to medical school graduation. There were 5 college graduates included in the sample. The majority of our subjects had had semi-skilled occupations, but there were included 2 retired physicians, a librarian, a chemist, a lawyer, and a draftsman. Each man in the sample was ambulatory and capable of self care, despite the presence of some physical disability. The disability prevented the man from maintaining himself adequately enough outside the domiciliary setting, but was not severe enough to require hospitalization. Subjects with gross psychiatric, brain syndrome, or physical disability which would interfere with task performance were excluded from the group.

Apparatus. A Bausch and Lomb Ortho-Rater, designed to measure depth perception, color blindness, visual acuity, and horizontal and vertical muscle balance was used as a visual screening device.

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To measure abstract reasoning ability, the Weigl-Goldstein-Sheerer Color Form Sorting Test was used. This test consists of a series of 12 geometric figures (4 triangles, 4 circles, 4 squares) with each figure in 4 different colors (red, blue, green, yellow). The subject is asked to sort the figures, then to explain the reason for his sorting. The scoring system devised by Thaler (1956) was used. In this system, performance is scored *1* if the subject sorts correctly according to color and form and gives adequate explanations for his two sortings. The subject receives a score of *2* if he sorts correctly, verbalizes adequately, but tends to build patterns with the figures. A score of 3 is assigned if sorting is adequate but the subject is unable to give reasons for sorting. If the subject is unable to shift voluntarily from the first sorting to the next one, but can do so after instruction, he is given a score of *4*. A score of 5 is given when the subject is unable to sort, even after instruction.

The problem-solving apparatus consists of a 5 ft. high, 2 ft. wide display board with a row of 12 equally-spaced signal lights at the head. At the foot of this board, and 8 in. forward, is the response board containing a row of 12 equally-spaced push buttons. A 2 ft. wide index card with randomized order of numbers from one to twelve is used. The position of the card varies with each of the three test stages. For Stage I the card is immediately above and behind the push buttons. For Stage II the card is midway between the lights and buttons. For Stage III the card is placed immediately below the lights. The control board, operated by the experimenter, consists of a light switch panel, timer, revolving switch, and power supply. This board is out of sight of the subject.

The following instructions were given to each subject: "Think of the lights on top as being numbered from one to twelve. When a light comes on, decide which number it is. Look for that number on the index card. Then press the button directly below that number. The light will go off when you press the right button. Then another light will go on, and your job again will be to select the correct button to press for the light to go off." The instructions were repeated for each of the three stages of the problem-solving task. In addition, demonstration, discussion, and two practice trials were repeated for each stage. Each stage consisted of ten trials, with each trial beginning as soon as the correct response for the previous trial was obtained. Errors (incorrect responses) and time per trial were recorded.

RESULTS

A measure of problem-solving ability was obtained by noting the total errors made at each of the three test stages. Table 1 shows the means, *SD*s, and total errors for each stage. The differences between the errors for each stage are statistically significant beyond the .05 level.

Table 1. Errors at Stages I, II, and III for All Subjects.

Stages	Means	*SD*	Total Errors
I	.79	1.05	23
II	3.76**	5.52	109
III	9.10*	11.79	264

* $p > .05$
** $p > .01$

Results of an analysis of variance of error scores, using McNemar's mixed model technique (1957), indicate that more errors occur as the task increases in difficulty (see Table 2).

Ability to deal effectively with abstract sorting material appears to correlate highly with problem-solving ability. Matching and comparing errors in the problem-solving performance of the "poorer" sorters (Scores 4 and 5) with errors in the "better" sorters' (Scores 1 and 2) performance yielded a biserial correlation coefficient of .53. This is significant beyond the .005 level.

It was found that most errors occurring at each of the problem-solving stages are produced by those subjects who exhibit poorest abstract-sorting ability. When this is examined by the analysis of variance technique, significant differences beyond .001 are shown. Figure 1 highlights the differential effects of task difficulty on level of abstract functioning. The differences depicted are significant beyond the .001 level as indicated in the sorting score-stage level interaction effect in Table 2.

The relationship between those visual functions measured by the Ortho-Rater and problem-solving ability appears to be statistically insignificant. The use of Spearman's Rank Difference Method with DuBois' correction results in coefficients of .12 between total errors and acuity, .19 between total errors and muscle balance, and −.08 between total errors and depth perception.

DISCUSSION

The increase in errors found with the changing positions of the index card (from Stage I to Stage III) confirms Kay's earlier results. His older subjects showed generally poorer perform-

Table 2. Summary of Analysis of Variance of Error Scores.

Source	*df*	*SS*	*MS*	*F*
Sorting Score (S)	3	2326.8111	775.6037	41.2733*
Difficulty Level (D)	2	1030.3678	515.1839	38.9168*
S x D (interaction)	6	469.7981	317.1214	23.9552*
S's (individual differences)	25	1092.7284	18.7919	
Residual	50	661.9038	13.2381	
Total	86	6391.6092		

* $p > .001$

ance than the younger subjects, accounting for more errors per stage and experiencing greater difficulty in shifting response patterns. However, difficulty with shifting response patterns has been found to occur, as well, in younger subjects under conditions of stress or anxiety (Donahue, 1956; Kay, 1954).

In the present study, in which aged subjects only were used, it was found that approximately half the group experienced little to no difficulty with the problem-solving task, while the remaining subjects experienced a fair amount of difficulty. In addition, it was found that abstract reasoning, as measured by the Sorting Test, related significantly to problem-solving ability. Those subjects whose abstract reasoning ability was lowest appeared much less adaptable to the changes called for by the changing positions of the index card. Demonstrating less flexibility in approach, they could not adjust as well to the changing demands of the problem-solving task.

The probability exists that this decreased ability is a function of central rather than peripheral factors. The lack of relationship between the tests of visual functions and problem-solving efficiency supports this general thesis, a thesis supported also by other studies (Birren, 1958; Shock, 1952). With task performance linked to a central process, task orientation becomes an important area for analysis.

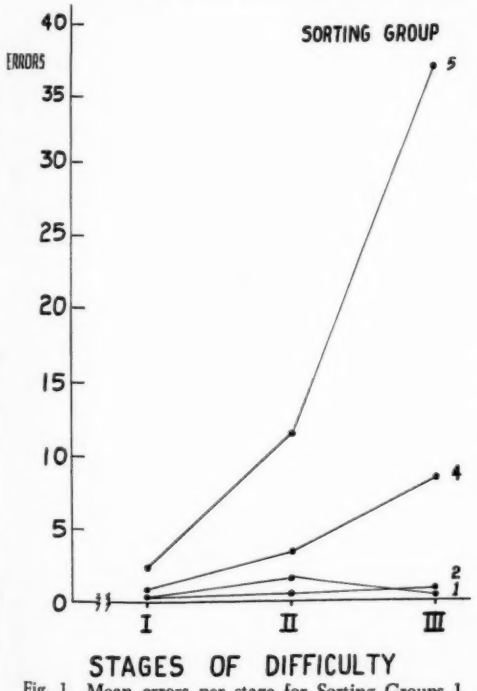

Fig. 1. Mean errors per stage for Sorting Groups 1, 2, 4, and 5.

The "high error" group demonstrated a lessened ability to shift voluntarily, and to reorganize stimulus information as the stages changed in the problem-solving task. This group also could not see beyond the superficial aspects of the Sorting Test, nor could they perceive as well the pertinent relationships involved in the task. Although this type of nonflexible performance has been noted to occur in normal younger subjects, the investigators believe that this feature of flexibility is correlated with age.

Other studies (Krugman, 1959; Welford, 1951) suggest that feelings of insecurity generally are more pronounced in older subjects. These feelings, expressed overtly as concern or worry about failure or success, can act to impede the learning of a new task, particularly if the task appears to measure ability. Such a demand might constitute a greater threat to older subjects, who are not strangers to evidence of deterioration or other disorganizing negative transfer. The examination of test behavior of older subjects in conjunction with administration of "anxiety-reducing" drugs may provide a technique for analyzing the relationship of anxiety to age and the intensity of its interfering nature. It should be recalled that the subjects in this study were institutionalized individuals who perhaps are less likely than others to be successful in meeting problems.

SUMMARY

This study, a modified replication of an earlier study by Kay (1954), investigated the relationships between the problem-solving ability and abstract reasoning ability of aged subjects. Following an initial visual screening test, 29 domiciliary members, aged 65-78, were administered the Weigl-Goldstein-Scheerer Color Form Sorting Test. The subjects then carried out a problem-solving task of three stages of difficulty.

The results showed no significant relationship between visual abilities and problem-solving performance. A highly significant relationship was found between abstract reasoning and problem-solving abilities. Those subjects who performed well on the Sorting Test made sig-

nificantly fewer total errors and significantly fewer errors per stage of difficulty than did the subjects whose abstract reasoning performance was low.

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THE LONG-TERM CONSTANCY OF BEHAVIOR: SENTENCE LENGTH

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It is widely held that the behavior patterns which prevail at the beginning of adulthood will, in the absence of strong disrupting influences, remain relatively constant throughout life. On theoretical grounds this belief is not likely to be challenged, yet it must be acknowledged that as yet very few systematic data have been presented to support it. It is not difficult to discover the reason for the paucity of data on this point. Proof or disproof of the hypothesis appears to require the longitudinal collection of data over a period of half a century or more. Few investigators have undertaken projects of this duration, nor are many likely to do so.[1]

In the case of some kinds of performances, however, investigations of the long-term constancy of behavior can be accomplished without the collection of new data. Certain long-term data are extant; and records of some forms of human behavior have been preserved. Among these are musical compositions, scientific papers, patents, paintings, literature and letters. If these are dated relative to their authors' ages, they become sources of information concerning the constancy of individual behavior. The investigator has previously urged the wider use of such documentary and historical material (Dennis, 1956 b). In previous studies making use of such data (Dennis, 1954; 1956 a), it was shown that a high degree of constancy characterizes the publication rates of most scientists. In long-lived persons this constancy usually extends from the beginning of scientific careers to age 80 or beyond.

The study reported in the present paper employed a research pattern similar to the one used in the earlier studies. The present problem was to determine the extent to which the mean sentence lengths of long-lived individuals remain constant throughout their adult years. Personal letters were chosen as sources of data because they are more comparable from person to person than are other forms of written material and because they are likely to be available for every decade of adult life.

SUBJECTS

Fourteen persons were chosen who met the following criteria: each lived to approximately age 80; and each, between ages 20 and 80, wrote letters in English that have been preserved and published. To minimize differences in English usage between historical periods, all but one of the persons chosen lived most of their lives within the nineteenth century. The subjects were: Robert Browning, Charles W. Eliot, John Evelyn, Francis Galton, Edmund Gosse, Edward Everett Hale, Henry Lee Higginson, James Martineau, George Meredith, Herbert Spencer, Harriett Beecher Stowe, Alfred Tennyson, Horace Walpole, and William Wordsworth. Of these persons, only two did not live to age 80. They were Browning and Gosse who at their deaths were 77 and 79 respectively. Consequently, the data for their eighth decades do not cover an entire ten-year period. John Evelyn lived in the 17th rather than in the 19th century.

PROCEDURE

From the correspondence of each subject a random sample of 50 sentences was obtained for each decade of life between the ages of 20 and 80. The number of published pages of correspondence for each subject in each decade occurring in the source used was first determined. This number was divided by 50 to obtain N. The first sentence on every Nth page was then used to build the sample of sentences, and the words in each sample were counted. For each sample of 50 sentences, the mean sentence length was then determined.

[1] The investigator is indebted to Professor Irving Lorge for calling to his attention that, more than sixty years ago, a professor of English, A. L. Sherman, in a book entitled *Analytics of Literature*, showed that each of several writers whose work he analyzed had a characteristic mean sentence length which was relatively constant. Sherman also showed that sentence length varied greatly in different periods of English literature. Sherman's quantitative treatment of written English seems to have received little attention. Sherman did not, however, analyze correspondence, nor did he cover life-spans as long as those with which the present study is concerned.

RESULTS

For each decade the group mean of the 14 subjects was determined. The group means showed no consistent trends, and a chi square test indicated that the differences among the means were not significant at the 5 per cent level. In other words, between the ages of 20 and 80, age and experience appear not to produce any increase or decrease in the length of sentences used in correspondence.

The extent of individual consistency in sentence length is indicated by the data in Table 1. This table shows the intercorrelations between sentence length for each pair of decades.

It will be seen that the correlations are for the most part high. In general, the correlations for the earlier decades are somewhat lower than those for the later decades, indicating that individual consistency becomes greater with age. This is in accordance with the findings of earlier studies on scientific productivity. However, in the case of most of these subjects, the letters which have been preserved are fewer for the early decades than for the later decades. The lesser consistency in the early period of life may therefore be due to the fact that the samples of 50 sentences provided less reliable indices for the early years. (No teen-age data were included in our study because for most of our subjects very few letters written before age 20 have been published.)

It should be noted that the intercorrelations in the sixth, seventh, and eighth decades of life are .94 and .95. If our subjects are representative, sentence length at ages 50-59 gives a very accurate prediction for the later years.

While the subjects of this study evidenced a high stability in their verbal behavior, it would not be correct to assume that sentence length is never subject to change. It is quite possible that the inclusion of several cases in which severe intellectual loss occurred would have materially affected our results; but the biographies of our subjects show that none of them suffered any marked senile deterioration. Results can perhaps be generalized then, only to a relatively healthy, non-pathological population.

In evaluating the consistency of our subjects with regard to sentence length, it should be noted that all of the subjects were engaged throughout their lives in written communication — all were habitual correspondents. In other words, we are dealing here with very firmly established behavior patterns. Less highly practiced forms of behavior might well show less constancy.

TABLE 1. INTERCORRELATIONS BETWEEN SENTENCE LENGTHS FOR 14 SUBJECTS AT SUCCESSIVE DECADES OF LIFE.

	Decades				
	30-39	40-49	50-59	60-69	70-79
Decades:					
20-29	.72	.89	.70	.64	.78
30-39		.82	.91	.87	.91
40-49			.91	.91	.88
50-59				.94	.95
60-69					.94

SUMMARY

The published correspondence of 14 long-lived persons was examined decade by decade from age 20 to age 80 with regard to mean sentence length. No general trend was found toward increase or decrease of sentence length with age. Individuals remained remarkably consistent over a period of six decades.

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A RESEARCH NOTE ON SUBCULTURAL DIFFERENCES IN WAIS BETWEEN AGED ITALIANS AND JEWS*

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The purpose of this study was to learn whether differences in psychometric patterns may be found between foreign-born Italian and Jewish aged.

SUBJECTS AND PROCEDURE

From a pool of 271 records of psychological tests administered within a period of three months to Jewish and Italian men and women aged 61 to 81, 33 pairs of cases which contained Full Scale WAIS IQs (Wechsler, 1955) were drawn. The cases were matched for subjects' socioeconomic backgrounds and, as far as possible, for age. The test scores were considered fair representations of the subjects' abilities.

The subjects were normal aged men (25 pairs) and women (8 pairs) who participated in the day center programs maintained by the New York City Department of Welfare and who had resided for many years in the foreign neighborhoods of New York City. (The investigator was not able to arrive at a meaningful and quantifiable measure of acculturation so as to enable him to equate the two groups on this variable.) The men were personal service, semi-skilled, or skilled workers. The women were housewives.

The mean Full Scale WAIS IQ for the groups was 83.33, with an *SD* of 12.36. The range was 62-117.

The mean CA for the Jewish group was 68.9 (range 61-79); mean CA of the Italian group was 70.55 (range 61-81).

RESULTS

The data shown in Table 1 indicate that the Jews had significantly higher verbal IQs than the Italians, while the latter had significantly higher performance IQs than the Jews. It is further to be noted that these differences were consistent for all the subtests.

The difference ($d = 6.85$) between the verbal and performance IQs for the Jewish group is significant ($t = 2.98$) at the .01 level of confidence. The difference ($d = 2.24$) between the verbal and performance IQs of the Italian group is not statistically significant ($t = 0.95$). These results indicate the need for cautious interpretation of differences between verbal and performance IQs among aged persons. A careful evaluation of the influence of cultural background upon test performance must be made before these differences can be interpreted as being due to psychopathology.

Our findings confirm earlier research in which Jewish and Italian bilingal children were compared. The Jewish children were found to do better than the Italian in verbal tasks, and the Italian children surpassed the Jewish in performance tasks (Bere, 1924). A recent study of Jewish and Italian native-born children, paired for Full Scale WISC (Wechsler, 1949)

TABLE 1. WAIS SCORES OF JEWISH AND ITALIAN SUBJECTS.

	No. of pairs	Jewish mean ($N = 33$)	Italian mean ($N = 33$)	Diff.	t
WAIS Verbal	33	87.15	83.21	3.94	3.58**
WAIS Performance	33	80.30	85.45	−5.15	−3.73**
WAIS Verbal Subtests:					
Information	33	7.97	7.24	.73	1.46
Comprehension	33	8.66	6.48	2.18	4.68**
Arithmetic	32[a]	8.91	8.59	.59	1.64
Similarities	32[a]	5.00	3.66	1.34	1.63
Digit Span	33	8.48	7.58	.91	1.63
Vocabulary	32[a]	6.66	6.60	.63	1.43
WAIS Performance Subtests:					
Digit Symbol	31[a]	7.29	7.61	−.32	−1.25
Picture Completion	33	6.36	6.61	−.24	−.47
Block Design	33	6.66	6.97	−.30	−.60
Pic. Arrangement	31[a]	5.35	6.45	−1.10	−1.80
Object Assembly	32[a]	6.19	7.59	−1.41	−2.23*

NOTE.—Negative values in favor of the Italian subjects.
[a] Some subjects unable to complete subtest.
* Significant at the 5 per cent level of confidence.
** Significant at the 1 per cent level of confidence.

* The investigator wishes to express his appreciation to Harry Levine, Consultant on Aging, New York City Department of Welfare, and Benjamin Nelson, Case Supervisor of Bureau of Special Services, New York City Department of Welfare, for their cooperation in making this study possible. The investigator also wishes to thank Mrs. Madeline Greenberg, who has done the statistical computations.

also indicated that the Jewish children were better than the Italian in verbal abilities and the Italian children better than the Jewish in performance abilities (Levinson, in press).

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BOOK REVIEWS

Der Menschliche Lebenslauf als Psychologisches Problem (The Human Life Course as a Psychological Study). By CHARLOTTE BÜHLER, with HERMAN HARVEY and ELLA KUBE. 2nd ed. Göttingen, Germany: Verlag für Psychologie, Dr. C. J. Hogrefe, 1959. Pp. 182. No price indicated.

The first edition of this well-known book was published in 1932 as the first volume of a planned series of reports on the human life cycle by the group of able young psychologists whom Charlotte Bühler had gathered around her. It was truly a pioneer work. When, during the 1940's, psychologists and sociologists began to interest themselves in the events of adulthood and old age, they found this book a source of stimulating ideas. Meanwhile Dr. Bühler had emigrated to the United States, as had several of the persons who had worked with her on the first edition of the book, among whom Paul Lazarsfeld, Egon Brunswik, and Else Frenkel-Brunswik are particularly well-known.

During her work in the United States, Charlotte Bühler has continued to be interested in the entire life cycle as an object of study, and in finding concepts to serve as a framework for theory and observation of adulthood and old age.

This book is the result of another quarter century of work and thought, and therefore is more than an ordinary second edition. The main section of the book is a substantially new work. It deals with the goal-structure of human life, aiming to set forth a theory of the dynamics and development of human goal-setting. Dr. Bühler recognizes the assistance of Ludwig von Bertalanffy in erecting a biological foundation for her theory.

The present book is based on a theory of four basic tendencies of life, which Bühler has stated before but not developed in great detail. These are: need-satisfaction, adaptive self-limitation, creative expansion, and maintenance of inner order. According to this theory, the individual life style represents a particular combination of the four basic life tendencies. Each of these tendencies dominates a particular sector of the life cycle, with need-satisfactions dominant in childhood, then adaptation, creative expansion, and finally, maintenance of inner order. The four life tendencies, when successfully integrated, lead in later life to a sense of fulfillment, which is the goal of life.

The second part of the book reproduces in shortened form the biographical material of the first edition, with the addition of some life-history material from Dr. Bühler's more recent clinical work. The earlier fruitful distinction between the biological and biographical life curves is used again in this edition of the book, but not stressed as much as in the earlier edition. Dr. Bühler recognizes that the individual's storing up of experience and wisdom enables him to maintain a high level of social function in his later years, in spite of the decline in his biological functions.

This book is useful for all people who are interested in understanding the entire human life cycle as a lawful phenomenon with individual variations. It draws upon recent German psychological research and thinking as well as on the American work.

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Economic Security for the Aged in the United States and Canada: A Summary. By GEORGE M. HOUGHAM. Ottawa, Ontario: Canadian Welfare Council, 55 Parkdale Avenue, 1959. Pp. 82. $1.50. (Multilithed)

This summary is of a lengthy report on economic security for the aged commissioned by the Canadian government and prepared by Dr. Robert M. Clark, Professor of Economics at the University of British Columbia. It gives a clear and simple description of the systems of social security for older people maintained by the United States and Canada. The comparisons are objective and throw a most useful light on the two quite different systems. Dr. Clark gives the pros and cons for the development of a contributory program with variable benefits to supplement the present flat rate old age pension which goes to everybody in Canada who reaches the age of 70. (Eds.)

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CHAPMAN, FREDERICK M. *Recreation Activities for the Handicapped.* New York: Ronald Press, 1960. Pp. xi + 309. $5.75.

FEDERATION EMPLOYMENT AND GUIDANCE SERVICE. *Survey of Employers' Practices and Policies in the Hiring of Physically Impaired Workers.* New York: The Service, 42 East 41st Street, 1959. No price indicated. (paper)

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Section C

Organization Section
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INDEX TO CURRENT PERIODICAL LITERATURE

NATHAN W. SHOCK

Gerontology Branch
National Heart Institute
National Institutes of Health

THE subject categories are those in *A Classified Bibliography of Gerontology and Geriatrics* by Nathan W. Shock published by Stanford University Press, Stanford, California (1951). Only major headings are used and the Roman numerals correspond to those given in the bibliography. In so far as possible, references are classified according to organ systems. Thus, most of the material on Geriatrics will be found under the organ system involved in the disease. Cross references are indicated by number at the end of each section. When available, abstract references are given *(B.A.—Biological Abstracts, P.A.—Psychological Abstracts,* and *P.I.—Population Index).* Abbreviations for journals are those used in *A World List of Scientific Periodicals Published in the years 1900-1933, 2nd Edition.* For journals not listed, abbreviations were devised according to the general rules used in the above source. It is impossible to cover all journals and list all papers concerned with aging and the aged. Authors and publishers are requested to call attention to publications or to send reprints to the Gerontology Branch, Baltimore City Hospitals, Baltimore 24, Maryland. The assistance of the Forest Park Foundation, Peoria, Illinois, in the preparation of these materials is gratefully acknowledged.

GERONTOLOGY

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